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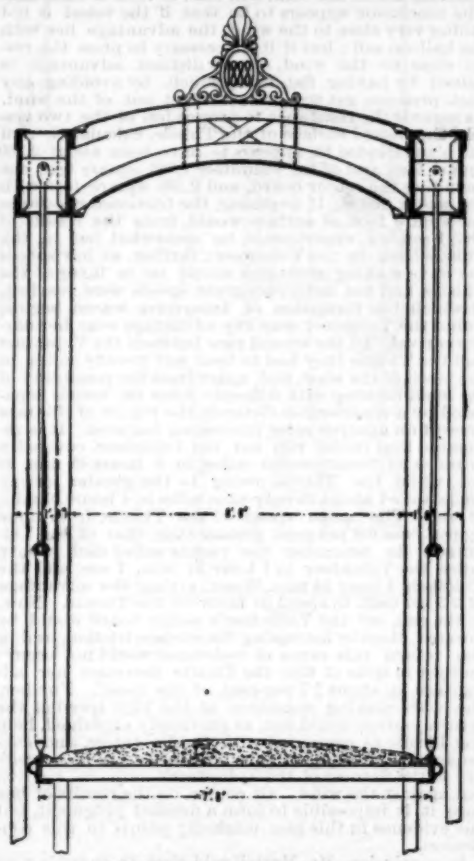
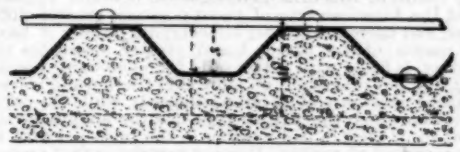
FOOT BRIDGE OVER THE RIVER OUSE AT BEDFORD.

THE corporation of Bedford having acquired land adjacent to the Duck Mill, on the south side of the river, for a public recreation ground, it was necessary, in order to make the site available and easy of access, to span the river at this point with a foot bridge. The river bank on the north side is laid out as an ornamental garden for a distance of about a mile and a half; and as the corporation would not allow the view along this bank to be interrupted in any way, and as they also insisted upon having a clear waterway of 15 ft. in the center of the river, it was a very difficult matter to design a bridge that should have practically no abutments. The difficulty was overcome by adopting the type of bridge illustrated herewith. The bridge consists of two arched ribs, with the roadway suspended from them, the clear span being 100 ft. and the width of footway 7 ft. The arched ribs each consist of four angles 4 in. by 3 in. by $\frac{7}{16}$ in., braced together by angle irons 3 in. by 3 in. by $\frac{1}{4}$ in. and 2½ in. by 2½ in. by $\frac{1}{4}$ in., and flat bars 3 in. by $\frac{1}{4}$ in., and 2½ in. by $\frac{1}{4}$ in.; the ribs are 1 ft. 6 in. deep by 1 ft. wide at the center, increasing in width to the abutments, where they are also splayed out horizontally to withstand the wind pressure. The two ribs are connected at the center with an angle iron frame, surmounted by ornamental wrought iron scroll work carrying the borough arms. The suspension rods are ¾ in. diam., attached to the vertical members of the rib by 1 in. pins at intervals of 5 ft., and to the angle iron stringer beams which carry the roadway. The roadway consists of corrugated flooring plates ¼ in. thick, 3 in. deep, and 1 ft. pitch, made by Messrs. Westwood, Baillie & Co. The plates are covered with concrete of cement and granite chippings, and as the first part of the roadway is necessarily rather steep, it is stepped out into 2 ft. 6 in. treads, with a 3 in. rise. The stringer beams, to which the flooring plates are riveted, are of angle irons 6 in. by 3 in. by ½ in., bent to a radius of 114 ft., having a versed sine of 11 ft. 6 in.; and an ornamental rolled iron is riveted to each with countersunk rivets. The hand railing is made of flat bars 1½ in. by ¼ in., bent and welded as shown, and attached to the suspension rods, which are flattened to receive them. The foundations are of Portland cement concrete, in the proportion of seven to one, the main ribs being bolted to blocks of Whatstandwell stone. Two ornamental cast iron pillars are fixed at each approach, and terminate the hand railing. The total weight of the iron work—including flooring plates, bolts, ornamental pillars, etc.—is under 18½ tons. The bridge was designed by Mr. John J. Webster, Liverpool, and erected under his superintendence. The contractors for the work were Messrs. E. Page & Co., Victoria, and Bedford Iron Works, Bedford.—*Industries.*

A TELEPHONE has been fitted up between the Hospice on the Great St. Bernard and the valley below, and the monks are now informed when travelers start to ascend the pass. If they do not appear within a proper time, servants are sent to meet them.



SECTIONAL ELEVATION.

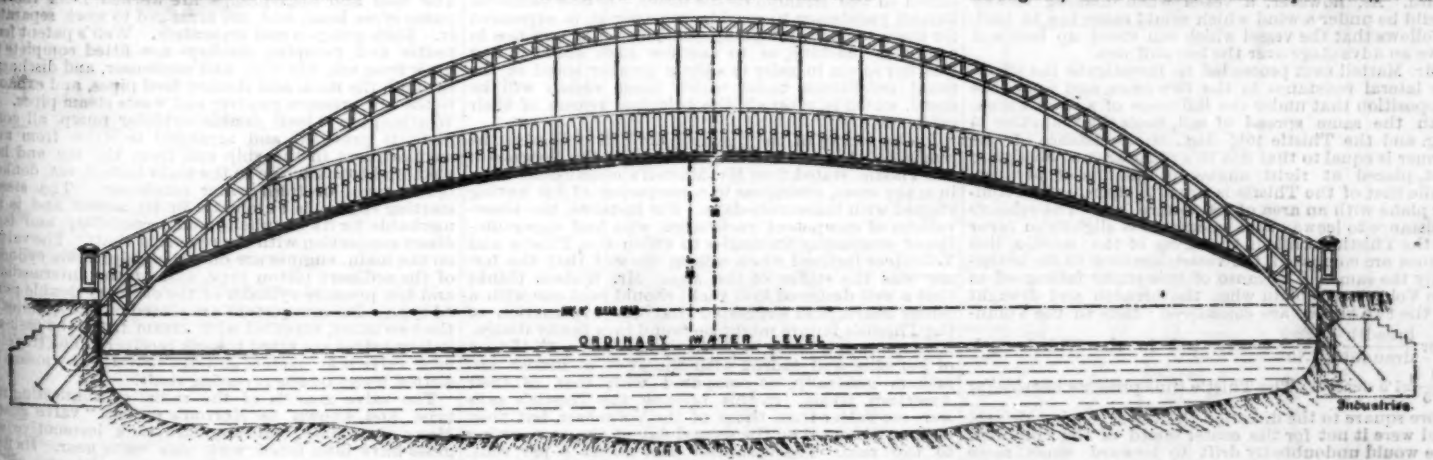


SECTION THROUGH ROADWAY

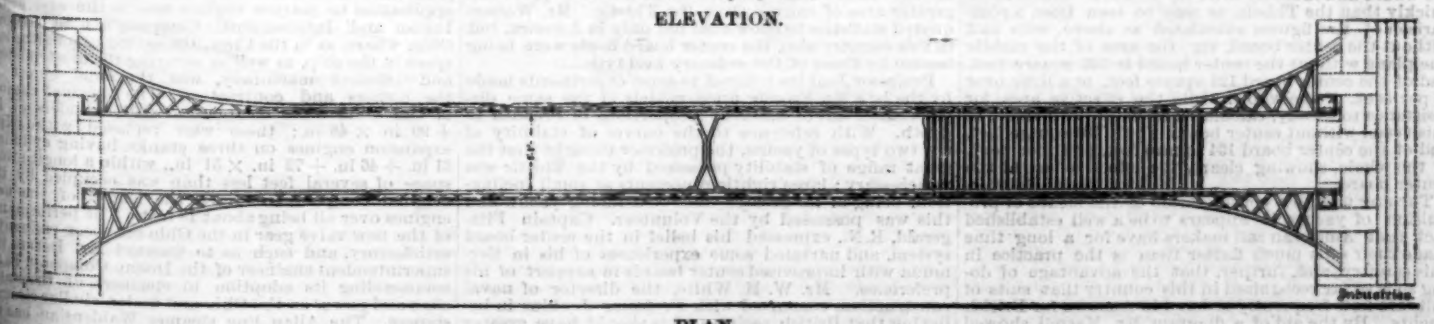
ON THE COMPARATIVE MERITS OF DEEP KEEL AND CENTER BOARD YACHTS FOR RACING PURPOSES.

AT the recent meeting of the Institution of Naval Architects at Glasgow, Mr. B. Martell, the chief surveyor of Lloyd's Register of British and Foreign Shipping, read a paper entitled as above.

Mr. Martell admitted at the commencement of his paper that a great deal of the data upon which his conclusions were based had been obtained from the newspapers and other similar channels of information. He had been compelled to have recourse to such sources, because all his efforts to obtain drawings of the celebrated yachts Thistle and Volunteer, in order that an exact comparison might be made of several of their noteworthy features, had been unsuccessful. As, however, Mr. Martell subsequently pointed out during the course of the discussion, his object was not so much to speak precisely regarding these two particular yachts as to make comparisons between the merits of the systems which they represent, and for this purpose his figures were sufficiently near the truth. Mr. Martell said: In our own yachting circles, the tendency for some years has been in the direction of decreasing the beam, and to acquire the necessary displacement by increasing the draught. The loss of stability initially, and indeed at all inclinations at which yachts usually sail, resulting from decrease of beam has been compensated for in practice by carrying large quantities of ballast, amounting in some instances to even more than the weight of the hull, spars, and equipment combined. This diminution of breadth has been carried out of late years to an extent which many experienced yachting men have regarded with disfavor. The tendency, no doubt, has been fostered by the retention in the minds of many of the erroneous ideas upon the subject of resistance prevalent for many years, and which led to the construction of comparatively narrow and unsafe vessels for general mercantile purposes. Our knowledge of the resistance of ships, which we owe to the patient investigation of the late Mr. Froude and his son, scant though it be, is sufficient to show that increase of beam is not necessarily associated with increase of resistance. As soon as that fact, in connection with other advantages which breadth gives, became sufficiently impressed upon men's minds, a rapid change in the proportions of vessels built for the mercantile marine at once took place. The same change, however, has not taken place in the design of British yachts. Perhaps to some extent, in addition to the foregoing considerations, this was owing to the tonnage rule under which yachts, until recently, were sailed. This rule did not take cognizance of depth, and no restriction, therefore, was placed on its increase to any extent which might be considered advantageous. Our Transatlantic kinsmen, who were not hampered by such tonnage laws, have, on the other hand, placed confidence in breadth of beam and shallow draught, it being apparently their opinion that a vessel of that type would "skim" over the water, instead of having to "plow through it," as in the case of the deeper draught vessel



ELEVATION.



PLAN.

FOOT BRIDGE OVER THE RIVER OUSE.

of the narrow type. They long ago, however, discovered that such vessels, without artificial means of preventing leeway, were not superior to, if as good as, those having a greater hold of the water. Hence the introduction of the center board. Having thus cursorily traced the growth of the two types of yachts, Mr. Martell proceeded to discuss briefly some of the advantages which they independently possess. Breadth of beam, he said, is essential to initial stiffness, if stiffness is to be secured by form alone, or even by form mainly. The narrow, deep yacht has necessarily a low position of the metacenter, and an adequate interval between the metacenter and the center of gravity can only be secured by artificial means—that is to say, by the use of a large quantity of ballast. The shallow, broad yacht, on the other hand, possesses initial stiffness due to form alone, and although ballast is carried in these vessels also, it is not required to anything like the same extent, and is useful mainly in lengthening out the range of stability. As a matter of fact, therefore, the one yacht is able to stand up under her canvas in a breeze with a small amount of ballast by reason of the stability due to her form, while the other cannot do so without the aid of a large quantity of ballast. As regards this feature of initial stability, which is of the utmost importance in racing yachts, since it practically determines the area of sail to be carried, there is, in my opinion, no doubt that the advantage is on the side of the broad, shallow vessel. Initial stability can be gained more easily and more rapidly by increase of beam than by increase of ballast. The Thistle has doubtless considerable initial stability, and carries a comparatively great spread of sail; but she must be regarded as a compromise between the two types, and scarcely representative of either. The broad yacht can usually carry at the same inclination, in the same breeze, a larger quantity of sail than the narrow, ballasted yacht of the same length and same area of immersed section; or, if both be provided with the same spread of sail, she will stand up better under her canvas, and thus have her sail area more advantageously disposed for receiving the wind's pressure; and this is so at all inclinations at which yachts are usually sailed.

With a view to comparing the Thistle and the Volunteer in this respect, the stability has been estimated from the data referred to, and as a result it is found that the metacentric height of the Thistle is 3·2 ft. and that of the Volunteer 4 ft. The Volunteer reaches her angle of maximum stability at about 28 deg., and beyond this the moment of stability continuously decreases until the angle of about 76 deg. is reached, when the stability vanishes. The Thistle, on the other hand, although possessed of less stability at small angles of heel, does not reach her maximum stability until about 55 deg. of inclination, and at 90 deg. she has still a large righting moment. Such a vessel is of course uncapsizable, while it is questionable whether the Volunteer could be considered safe for an oversea voyage, subject to the sudden gales which might be encountered; or at least, if a race were sailed in the open sea in bad weather, whether it would not be considered prudent or necessary to reduce the sail spread in weather in which the Thistle could carry all her plain sail with perfect safety.

Passing from the consideration of stability or ability to stand up under canvas, we come next to the important question of leeway. Running before the wind, the British yacht is quite as fast as the American of the same size, if the spread of canvas be as great. The records appear to show that the Thistle was even superior to the Volunteer in this respect; but, of course, in judging of this, it must be borne in mind that vessels separated by a considerable distance may be subject to great differences in wind pressure, which would possibly account for the Thistle gaining slightly on the Volunteer on returning in the second race. If area of middle line longitudinal plane only be considered as a measure of the resistance to leeway, the cause of the superiority of the American vessel will not be evident, as this would appear to be practically the same in the two vessels; namely, 853 square feet in the Thistle, and 856 square feet in the Volunteer, including the center board. As, however, a vessel when making leeway would be under a wind which would cause her to heel, it follows that the vessel which can stand up best will have an advantage over the less stiff one.

Mr. Martell next proceeded to investigate the effective lateral resistance in the two cases, and upon the supposition that under the influence of a wind which, with the same spread of sail, heels the Volunteer 15 deg. and the Thistle 16¼ deg., the resistance of the former is equal to that due to a plane area of 708 square feet, placed at right angles to the line of advance, while that of the Thistle is equal to that due to a similar plane with an area of 780 square feet. The relative resistance to leeway thus calculated is slightly in favor of the Thistle; while if the areas of the middle line planes are compared, the vessels are seen to be practically the same. The cause of this slight falling off in the Volunteer is plain when the breadth and draught of the two vessels are considered; thus in the Volunteer $\frac{\text{breadth}}{\text{draught}} = \frac{22·2}{10} = 2·22$, and in the Thistle it is $\frac{20}{13·5} = 1·5$ nearly. The Thistle thus presents her side far more square to the direction the vessel is being driven, and were it not for the center board of the Volunteer she would undoubtedly drift to leeward much more quickly than the Thistle, as may be seen from a comparison of the figures calculated as above, with and without the center board, viz., the area of the middle line plane without the center board is 732 square feet, and of the center board 124 square feet, or a little over 16 per cent. of the whole, while the effective area for resistance to leeway, calculated as before explained, of this vessel without center board is only 634 square feet, and of the center board 134 square feet, or 21 per cent. of the whole, showing clearly the effectiveness of the center board.

Turning now to a consideration of the means of propulsion of yachts, it appears to be a well established fact that American sail makers have for a long time made their sails much flatter than is the practice in this country, and, further, that the advantage of doing so is so far recognized in this country that suits of sails are now frequently ordered in America for British yachts. By the aid of a diagram Mr. Martell showed that when a yacht is sailing with the wind, not greatly before the beam, a "bagginess" in a sail—especially a jib—would not give such good results as a plane surface.

The late Mr. Froude, at the Institution of Civil Engineers, mentioned cases where the rounded cut of the luff of a jib produced a bagginess just abaft the stay, which swelled out under the influence of the wind so much that the "bag" could be seen on the fore side of the stay by an onlooker standing square to the vessel's course. In such a case the sail's action on both stay and bolt rope is propulsive; but it is evident such a sail would soon "lift" if the vessel were forced close to the wind, owing to the wind pressure on the back of the fore part of the sail being at least equal to that on the fore side. Indeed, it is evident from a consideration of the diagram that when the vessel is sailing close to the wind, any considerable amount of ballooning of the sail will cause the fore part to be parallel, or nearly so, to the direction of the wind, when its propulsive effect would be lost, while the after part of the sail standing across the wind will tend to form a back sail. The conclusion appears to be that if the vessel is not sailing very close to the wind, the advantage lies with the balloon sail; but if it is necessary to press the vessel close to the wind, a very distinct advantage is gained by having flat sails, which, by avoiding any back pressure, get the utmost effect out of the wind. As regards the resistance to propulsion of the two vessels, the wetted surface of the Thistle, calculated from the plans alluded to, appears to have been about 2,160 square feet, and of the Volunteer 1,980 square feet, not including the center board, and 2,280 square feet with the center board. If anything, the frictional resistance per square foot of surface would, from the results of Mr. Froude's experiments, be somewhat less in the Thistle than in the Volunteer; further, at low speeds the wave-making resistance would be in favor of the Thistle, and not until very great speeds were reached, at which the formation of transverse waves begins, would the Volunteer reap any advantage over her narrower rival. In the second race between the Volunteer and the Thistle they had to beat out twenty miles in the teeth of the wind, and, apart from the possibility of the wind blowing with different force on vessels separated by a considerable distance, the results of this race present on analysis some interesting features. It is estimated that in the run out the Volunteer covered a distance of twenty-seven miles in 3 hours 45 min. 50 sec., while the Thistle, owing to the greater leeway made, sailed about twenty-nine miles in 4 hours, 0 min. 30 sec. The mean speed of the Thistle, from these figures, was 0·8 per cent. greater than that of the Volunteer. In returning the yachts sailed each twenty miles, the Volunteer in 1 hour 57 min. 7 sec. and the Thistle in 1 hour 54 min. 12 sec., giving the advantage of 2·5 per cent. in speed in favor of the Thistle. Now, in the run out the Volunteer's center board would be lowered, thereby increasing the surface friction, and in the return this cause of resistance would not occur; and yet in spite of this the Thistle increases her advantage by about 1·7 per cent. of the speed. Further, the wave-making resistance at the high speed of the return journey could not, as previously explained, help the Thistle as compared with the Volunteer, and consequently the whole of this difference must be accredited to the flatness of the Volunteer's sails in beating out against the wind. Of course, on the results of one race it is impossible to form a decided judgment, but the evidence in this case markedly points to this conclusion.

In conclusion, Mr. Martell said that, in summing up the results of this brief investigation, it would appear that the American type of yacht possesses greater stiffness, and therefore greater sail-carrying power; it has, by reason of the center board, greater resistance to leeway, is fitted with better sails for close-hauled sailing, and has practically no more skin friction and wave-making resistance at all ordinary speeds, while the only point on which the British type has the advantage is, that she is safer in bad weather in the open sea with a large spread of canvas. It is not surprising that under these circumstances all the recent trials of speed between the British and American types should have resulted in the triumph of the latter. It now behooves British yachtsmen to consider whether it is expedient for them to make sea-going qualities a *sine qua non* in a racing machine, or to sacrifice high speed in bad weather at sea in order to obtain greater speed in the usual conditions under which these vessels will be raced, which is, after all, the principal reason of their existence.

In the course of the discussion which followed the reading of this paper, Mr. G. L. Watson, the designer of the Thistle, stated that Mr. Martell's conclusions were, in many cases, erroneous in consequence of his having started with inaccurate data. For instance, the observations of competent yachtsmen, who had opportunities of comparing the angles to which the Thistle and Volunteer inclined when sailing, showed that the former was the stiffer of the two. Mr. Watson thinks that a well designed keel yacht should beat one with a center board, and suggested that the explanation of the Thistle's failure might be found in a faulty design. He expressed himself as perfectly satisfied with the set of her sails, and indeed with the work of British sail makers generally, as compared with that of their American rivals. In his opinion the Thistle's sails were set flatter than those of the Volunteer, but they became distorted on the second day of the race, owing to the rain. The Volunteer had about 8 per cent. greater area of canvas than the Thistle. Mr. Watson quoted statistics to show that not only in America, but in this country also, the center board boats were being beaten by those of the ordinary keel type.

Professor Jenkins referred to some experiments made by the late Mr. Froude upon models of the same displacement, but of different proportions of breadth to depth. With reference to the curves of stability of the two types of yachts, the professor thought that the great range of stability possessed by the Thistle was unnecessary; large righting moments at small inclinations being of far greater value to a racing yacht, and this was possessed by the Volunteer. Captain Fitzgerald, R.N., expressed his belief in the center-board system, and narrated some experiences of his in Bermuda with improvised center boards in support of his preference. Mr. W. H. White, the director of naval construction, concurred with Professor Jenkins in believing that British racing yachts should have greater beam than is now usual. Messrs. West, Lamont, and Major Baker joined in the discussion; the latter gentleman humorously calling attention to the common summer announcements in American newspapers under the heading of "The Week's Capsizes." Major Baker thought the center board yacht unsafe, and believed that increased beam is accompanied with augmented resistance. Mr. Martell having briefly replied, was heartily thanked for his interesting communication.

THE MORTON VALVE GEAR.

THE SS. Circe, of the Donaldson Brothers' line of North American steamers, was built on the Clyde in 1874, and fitted with compound surface condensing engines, having cylinders 37 inches and 74 inches diameter respectively by 48 inches stroke. The vessel was recently placed in the hands of Messrs. Barclay, Curle & Co., of Glasgow, to receive a thorough overhaul and structural alterations, as well as to be fitted with modern propelling machinery. The net results of the alterations and refit are that triple expansion engines on three cranks, having cylinders 25 inches and 41 inches and 68 inches diameter respectively by 48 inches stroke, and new double-ended boilers of ample capacity to supply steam of 160 pounds pressure by natural draught, have been arranged and placed in 6 feet less fore and aft space than the engines and boilers originally occupied, the new machinery giving an addition of 900 I. H. P. available for the propulsion of the vessel.

In order to obtain this increased propelling power with modern machinery, without increasing the length of the machinery compartments, and at the same time provide duplicate crank shafts, with ample bearing surfaces and complete freedom of access to all the moving parts, and retain the whole working parts within sight from the starting platform, as well as obtain an arrangement of cylinders which should minimize the length of the steam passages from cylinder to cylinder, the second and third cylinders are placed as close together as the flanges of their covers will permit, and the valves are placed on the starting or opposite side of the engine from the condenser and pumps, each being directly on the cross line of its cylinder, an arrangement which tends to distribute the weight on each side of the center line of the engine, as well as greatly to facilitate the examination of the valves and valve faces. The exhaust from the third cylinder is carried round the outside of the cylinder. The distance between the second and the first cylinder is made equal to the distance between the second and third, thus allowing the duplication of the crank shafts. The cylinders are supported on one side by three cast iron columns. On to these columns the guides for the slippers are attached, and an arrangement for circulating water to the back of the guides is carried out. On the starting side of the engine four wrought iron columns are put up for carrying the cylinders, bolted at the top to the cylinders and at the bottom to the sole plate. The sole plate is made in two parts bolted together in the center, and has four bearings into which are fitted cast iron boxes fitted with patent metal strips; each bearing is 24 inches long. The crank shaft is in two duplicate parts; each main bearing is 13½ inches diameter, and the crank pins are 13¾ inches diameter each. The shaft is of wrought iron, and the pins are of steel. The webs and pins are built upon the shaft. The two duplicate portions have flanges formed in their outer and inner ends, for which recesses are formed in the webs of the intermediate crank, by which flanges the two duplicate parts are connected to the intermediate portion by means of fitted bolts, the heads of the bolts being to the outside of the webs next to the inner main bearings, thus forming a substantial and compact as well as interchangeable crank shaft. The condenser is of the ordinary rectangular form, with a cooling surface of 3,500 square feet, supplied with the condensing water by a 12 inch centrifugal pump. The air, feed, and bilge pumps are worked from the low pressure engine cross head, through double plate levers of the usual form. The turning gear is of a compact and very substantial arrangement, with sufficient power to turn the main engine one revolution in ten minutes. The feed and bilge pumps are worked from the air pump cross head, and are arranged to work separately. Each pump is cast separately. Weir's patent feed heater and pumping donkeys are fitted complete to draw from sea, hot well, and condenser, and discharge through the main and donkey feed pipes, and exhaust to the low pressure receiver and waste steam pipes. A Worthington 9 inch double cylinder pump, all complete, is provided and arranged to draw from any compartment in the ship and from the sea and hot well, and to discharge to the main boilers, sea, donkey boiler, main or fresh water condenser. The steam starting engine is automatic in its action, and is remarkable for its simplicity and accessibility, and is in direct connection with the reversing shaft. The valves on the main engines are on the high pressure cylinder of the ordinary piston type, and on the intermediate and low pressure cylinder of the ordinary double ported type. Balance pistons are placed on the spindles of the two latter, supplied with steam from the casings. Safety valves are fitted to each receiver. The travel of each valve is 5¼ inches, and can be varied by means of slotted levers on the reversing shaft.

The valve gear is of the radial or connecting-rod type, and known as Morton's patent "valve gear." Many stationary, tramway, and tank locomotive engines have been fitted with this valve gear. Its first application to marine engines was in the case of the Inman and International Company's mail steamer Ohio, where, as in the Circe, the saving of longitudinal space in the ship, as well as securing the most modern and efficient machinery, was the chief object of the owners and contractors. The original engines of the Ohio were compound, with cylinders 37 in. + 90 in. × 48 in.; these were replaced with triple expansion engines on three cranks, having cylinders 31 in. + 46 in. + 72 in. × 51 in., within a longitudinal space of several feet less than was occupied by the original compound engines, the length of the new engines over all being about 18 feet. The performance of the new valve gear in the Ohio has been eminently satisfactory, and such as to warrant Mr. Doran, the superintendent engineer of the Inman Company, in recommending its adoption in steamers of the same class and power as the Ohio and under similar circumstances. The Allan line steamer Waldensian has recently been converted to triple expansion by the addition of another engine to the forward end of the origi-

nal engines, which new engine was—under the direction of Mr. David Johnston, superintendent engineer of the company at Glasgow—fitted with the Morton valve gear, and on the recent trial trips in the Firth of Clyde gave unqualified satisfaction. The original eccentrics and link motion are retained on the intermediate and

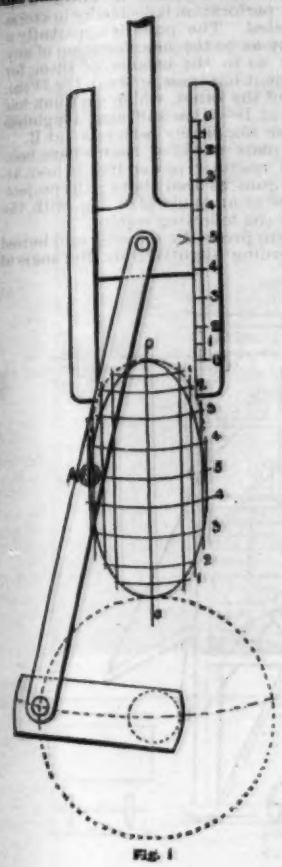


Fig. 1

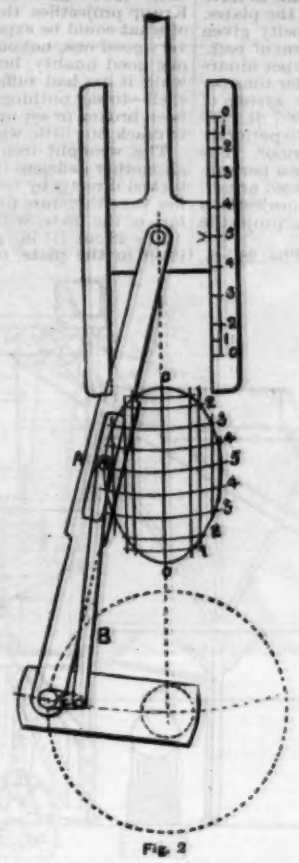


Fig. 2

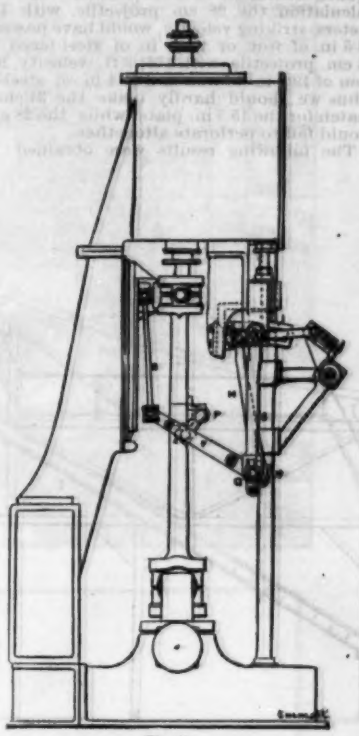
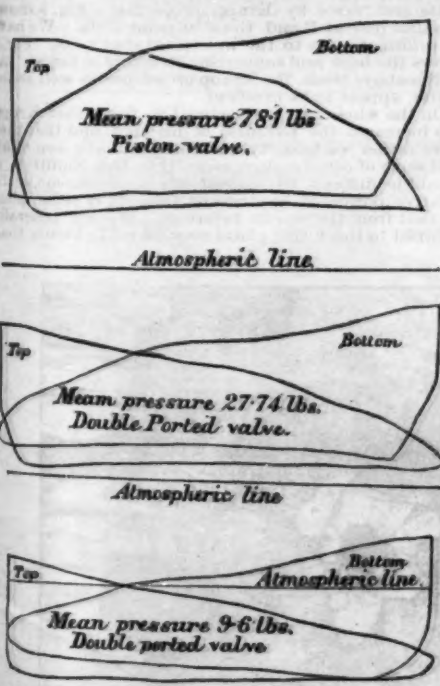


Fig. 3

MORTON'S VALVE GEAR

low pressure engines, so that the old and the new motions enable a comparison to be drawn as to the relative working efficiency and cost of upkeep.

It is well known that up to 1882 the engineering world had been familiar with the class of valve gear known as the Hackworth, Walschart, Brown, and Joy. Unlike any of these systems, the Morton gear has no eccentrics or angled cross slide; its chief feature is the method adopted to correct the angularity of the connecting rod, and the arrangement of mechanism whereby that correction is maintained, whether the engines be set in forward or backward gear, or in any intermediate grade of expansion. Equal port opening, and cut off for both ends of the cylinder, being thus given, or by a



Cylinders....25 in.+41 in.+66 in.×48 in.....	H.P.,	I.H.P.	734·15
Boiler pressure per gauge. 160 lb. per sq. in...	I.P.	"	791·4
Receiver " " 55 " ...	I.P.	"	667·6
	Total....		2,193·15
Vacuum pressure per gauge.....			26 in.
Revolutions per minute.....			79

suitable proportioning of the parts, the steam may be allowed to follow the piston further on the up stroke than on the down, which is a desirable arrangement in inverted cylinder engines. The lead is constant, and the motion of the valve is such that wire drawing and cushioning are reduced to a minimum; the motion of the valve being in unison with the stroke of the piston, instead of with the stroke of the crank or eccentric, the steam distribution is more regular than with any other system.

The figures herewith illustrate the details of the new gear. Its simplicity is evident. The diagram, Fig. 1, represents a piston rod head, connecting rod, and crank of an overhead cylinder engine, the full lines representing the irregular path described by a fixed point, A, on the line of the connecting rod, while the dotted outline shows the path that would be traced if the angularity of the connecting rod were corrected, and both ends of the elliptical figures made alike. It was found that when for a fixed point on the line of the connecting rod a movable point—Fig. 2, A—was substituted, the egg-shaped elliptical figure became exactly alike at both ends, as represented by the outline path shown by diagram, Fig. 2. In this figure the ordinates 1, 2, 3, 4, and 5 intersect each other, and agree exactly with the positions of the piston marked 1, 2, 3, 4, and 5 on the guide bar. The movable point, A, Fig. 2, receives its motion from an overhung or return crank, E, on the crank pin of the engine, through the link, B. This return crank, E, has been generally adopted for all outside cylinder locomotives and single crank engines, but for inside cylinder locomotive and marine engines, where the cranks are double, the movable point, A, receives its motion from the crosshead, as shown by the diagram, Fig. 3. Instead of sliding on the line of the connecting rod, as shown by Fig. 2, it now radiates with the short lever or spanner, P, centered in a projection on the connecting rod, and receives its motion from a point on the valve lever, F. The proportions are such that the versed sine of the spanner, P, will be equal to the versed sine of the lever, F, as is customary with this system when used as a parallel motion.

The driving end of the lever, F, is connected with the crosshead by means of the link, B, and its fulcrum end, N, is suspended by the links, C, vibrating from fixed centers at their upper ends. These links are parallel with the connecting rod when the engine is on the centers. It will now be seen that the radiating movable point, A, corrects the angularity both of the connecting rod and of the valve lever, F, by one motion. The movements of the links, C, in vibrating from right to left or left to right from the center line, in whatever direction the crank may revolve, are equal for equal increments of the travel of the piston. These conditions are maintained whether the engines are in forward or backward gear, or linked up to any intermediate position. The reversing portion of the gear consists of a sliding quadrant, I, properly secured so as to form part of the slide valve rod and to slide with it.

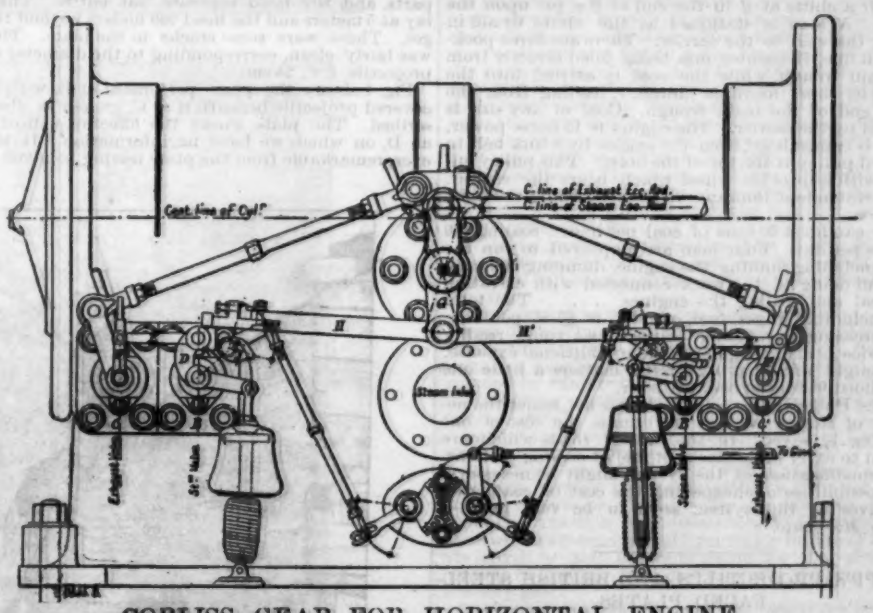
A bracket forms the guide for the valve spindle and quadrant, and has arms cast on it which carry the fixed center of the vibrating links, C. The arc of the quadrant, I, being the radius of the adjustable link, H, from the center, G, is fitted with a sliding block, J, capable of being thrown to the right or left from the center of the quadrant for forward or backward motion of the engine; consequently, when the engine is "on the centers," the upper end of the adjustable link, H, and its block, J, may travel through the whole range of the quadrant, I, from right to left, or *vice versa*, without moving the slide valve. This arrangement reduces to a minimum the wear of the block of the quadrant, for when it is once set in position for working, there is little or no motion.

The boilers are of the ordinary double-ended marine type, built of Parkhead mild steel throughout; the shells 13 ft. 6 in. diameter by 16 ft. long, for a working pressure of 160 lb.; three furnaces in each end of either boiler 3 ft. 2 in. inside diameter; Fox's patent corrugated furnaces; the holes all drilled and countersunk; and the total heating surface in the two boilers is 9,900 square feet. Two of Weir's circulators and Whitfield's fire bars are fitted in each boiler. The boilers were tested to 320 lb. pressure per square inch, and otherwise are to the Board of Trade requirements. The new engines and boilers were built from the specification of Mr. Archibald Blair, superintendent engineer for Messrs. Donaldson Brothers. The substantial and well-finished work is such that it well maintains the high reputation of the builders.—*The Engineer.*

MODIFIED CORLISS GEAR.

A. W. SMITH & Co., of the Eglinton Engine Works, Glasgow, show at the Glasgow Exhibition a compound engine, the high pressure cylinder being 17 in. and the low pressure 29 in. in diameter. The stroke is 42 in. The horse power is 300 indicated.

The chief point of interest, says *Engineering*, is the modified Corliss gear, which is here shown with one steam and one exhaust valve attached to each end. The eccentric rods give a vibrating motion to two wypers on one stud pin, A. One eccentric rod actuates the steam valves, B and B¹, which regulate the admission and cut-off. The other rod actuates the exhaust valves, C and C¹. There is nothing novel in the working of the exhaust valves. The outer ends of the steam valve spindles each carry a bell crank wyper, D and D¹. The vertical arms of these bell cranks are formed with a double jaw, which receives and is connected by means of a pin to horizontal steel bars, E and E¹. The small ends of these horizontal bars are jointed by means of a pin to vertical links, F and F¹. These links work freely and are simply carried at their lower ends on the projecting ends of the exhaust valve spindles. This arrangement gives a parallel movement to the horizontal bars, E and E¹, when the bell crank wypers, D and D¹, are put in motion. Then vibrating steam wyper, G, transmits a reciprocating motion to the two horizontal arms, H and H¹, to which it is connected by a pin attachment. The ends of these two arms, H and H¹, are fitted with steel adjustable pieces, which, in moving out from the steam wyper, come in contact



CORLISS GEAR FOR HORIZONTAL ENGINE.

with the ends of the horizontal bars, E and E¹, and give motion to the bell crank wypers, D and D¹, thus opening the steam valves. The ends of the horizontal arms, H and H¹, rest upon two cams, J and J¹, which are carried on a small shaft actuated by a system of wypers from the governor. It will be observed that as the arms, H and H¹, engage with the horizontal bars, E and E¹, the latter sink to a lower level until they sink under the end of arms, H and H¹. The horizontal arms of the bell cranks have attached to them steel spiral springs with a dash pot arrangement for closing the steam valves. As the cams, J and J¹, are moved round by the governor, the action raises or lowers the

ends of the horizontal arms, H and H¹, causing a variation in the period of engagement of the same with the end of the horizontal bars of the wypers, D and D¹, thus giving a correspondingly greater or less opening to the steam valve. The parts, D¹ and E¹, show the position of gear with the steam valve being opened and D E with the steam valve shut. With a varying cut-off the lead is practically the same.

The novelty Messrs. Smith claim for this arrangement is the mode of actuating the steam valve automatically by means of the combination of bell crank wypers, D and D¹, the horizontal bars, E and E¹, and the cams, J and J¹, acting with the horizontal arms, H and H¹, in conjunction with the governor.

COAL HOIST OF THE PHILADELPHIA AND READING RAILROAD.

THE method of hoisting coal for coaling locomotives which we illustrate this month is worthy of careful investigation by master mechanics. The hoist shown in the cut is one of two put in by the Philadelphia & Reading, and is located at Ninth and Green streets, Philadelphia, close by the passenger station of the road, and within half a stone's throw of the office of Superintendent Bonzano.

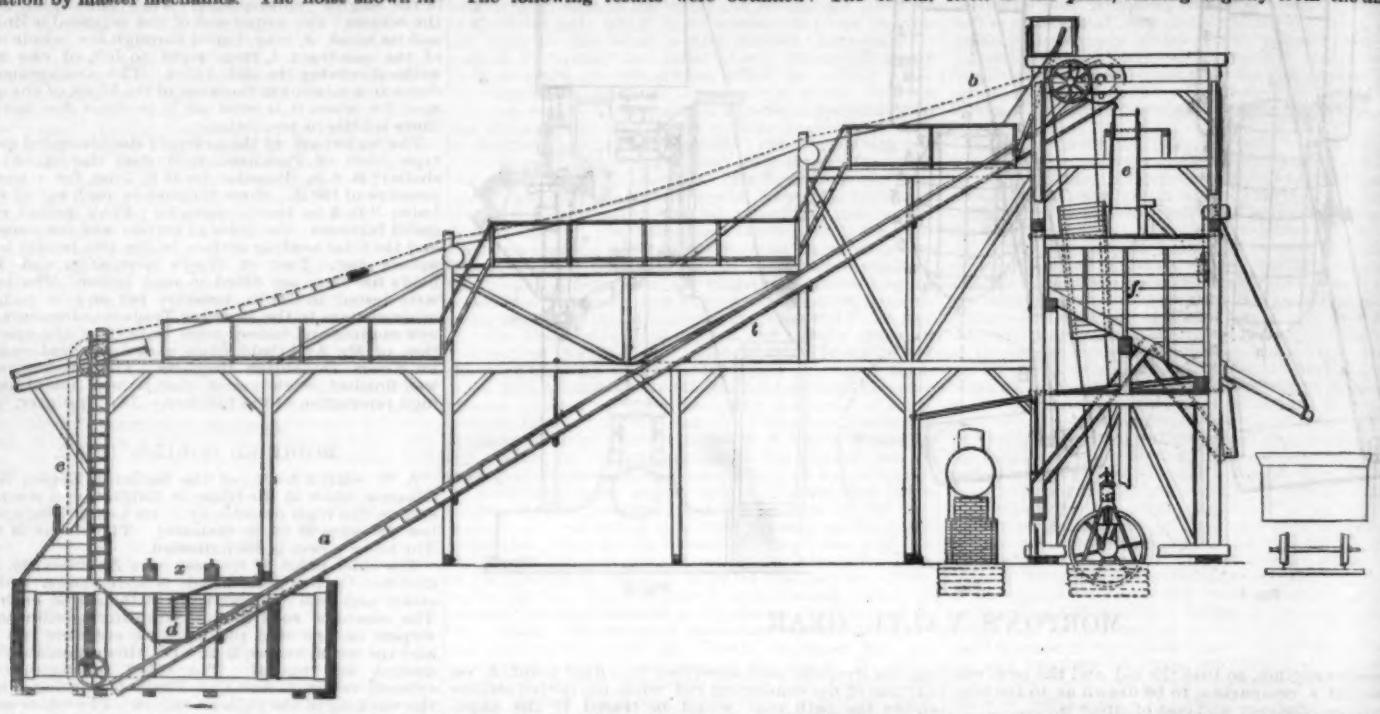
The general plan of the hoist can easily be understood from the engraving. The lower side of an endless link carrier, *a*, *b*, *c*, runs in a trough, *t*, which extends from the coal pit, *d*, to the top of the pockets. To this carrier, at intervals of about 30 inches, buckets—or rather scrapers—are attached, which are shaped to fit the interior of the trough. A coal car is pushed over the pit at *x* and dumped and the coal runs by gravity through a chute at *d* in the end of the pit upon the carrier. A man is stationed at this chute to aid in feeding the coal to the carrier. There are three pockets, *f*, in line, the center one being filled directly from the main trough, while the coal is carried into the others by short movable chutes, *e*, leading from the upper end of the main trough. Coal of any size is handled by the carrier. The engine is 15 horse power. Power is transmitted from the engine by a link belt to a geared pulley at the top of the hoist. This pulley engages with a sprocket wheel which bears the carrier.

Superintendent Bonzano writes concerning the hoist as follows:

"We can hoist 60 tons of coal per hour; coaling 100 engines per day. Four men are employed to run the hoist, including running the engine, dumping the cars, etc., and doing all the work connected with elevating the coal and coaling the engines. . . . The total cost, including wages, fuel, oil, etc., is $7.16 per day. By increasing our storage capacity we could readily coal twice as many engines without additional expense.

"I might add that by forcing matters a little one could hoist 90 tons of coal per hour."

As the Philadelphia and Reading is not under the necessity of storing coal at its dumps, the cost of one handling is saved. In the case of roads which are obliged to carry large stocks of fuel at coaling stations, some modification of the system might be necessary. The possibilities of cheapening the cost of coaling locomotives by this system seem to be very great.—*Master Mechanic.*



COAL HOIST OF THE PHILADELPHIA & READING, AT NINTH AND GREEN STS., PHILADELPHIA.

KRUPP'S PROJECTILES AND BRITISH STEEL-FACED PLATES.

IN the end of last year, and in last March, Krupp tried certain steel projectiles against steel-faced plates obtained from Messrs. Cammell. These plates he took as the recognized standard for steel faced armor. In comparison he tested a curved shield of his own made of steel for a circle of a diameter of 2 meters (6·56 ft.), 60 cm. (23·62 in.) thick. The Cammell steel-faced plates were 335 cm. (11 ft.) long, 372 cm. (9 ft.) wide, and 39·5 cm. (15·55 in.) thick, the backing being of oak 20 cm. (7·87 in.) thick. There was also for comparison a Cammell wrought iron plate of exactly the same dimensions as the steel-faced plate above mentioned. Against this the guns fired at a striking angle of 65 deg. with the face of the plate. The guns employed were 28 cm. (11·02 in.) and 24 cm. (9·45 in.). The former fired forged steel shells weighing 246·4 to 247·8 kg. (542·2 lb. to 546·3 lb.) with a striking velocity of from 469 to 470 meters (1,539 ft. to 1,542 ft.). The latter fired steel shells weighing from 214·3 to 212·4 kg. (472·5 lb. to 468·3 lb.) with a striking velocity of from 537 to 539 meters (1,762 ft. to 1,768 ft.).

The intention of Herr Krupp appears not to have been to match the two guns exactly against the plates, the smaller projectile having the higher velocity given to it. The two projectiles on Krupp's system of reckoning had for the 28 cm. gun 6·15 meter-tons per square centimeter, and for the 24 cm. gun 6·47 meter tons per square centimeter of cross section. On our system of calculation, the 28 cm. projectile, with 1538·7 ft. (469 meters) striking velocity, would have power to perforate 16·5 in. of iron or 12·21 in. of steel-faced armor. The 24 cm. projectile, with 1761·3 ft. velocity, has a perforation of 19·2 in. of iron and 15·4 in. of steel-faced armor. Thus we should hardly make the 24 cm. projectile a match for the 15·5 in. plate, while the 28 cm. projectile would fail to perforate altogether.

The following results were obtained: The 28 cm. and 24 cm. projectiles alike broke the Krupp hard steel shield into fragments, passing on 12 meters past the shield; the former was slightly set up and the latter slightly set up and cracked. The 28 cm. projectile buried itself in the steel-faced plate, the base being 10·5 cm. (4·13 in.) from the plate face, arguing a depth of perforation for the point of 62 cm. (24·4 in.) from the plate face, the shell not being broken, but remaining firmly held in the surrounding plate—see A, Fig. 1, which shows the front view of Cammell's 15·5 in. (39·5 cm.) steel-faced plate after attack by 28 and 24 cm. The 24 cm. projectile passed completely through the steel-faced plate. The shell broke up the body into two parts, and the head separate, but entire. The body lay at 5 meters and the head 230 meters beyond the target. There were some cracks in the plate. The hole was fairly clean, corresponding to the diameter of the projectile, *i. e.*, 24 cm.

Fig. 1 shows the plate perforated at B, with the recovered projectile beneath it at C, broken as above described. The plate shows the effect of a third round at D, on which we have no information. It is, however, remarkable from the plate having behaved so differently there and at B. It may be seen that at D the projectile has been kept out, and, we should be inclined to think, broken or set up, from the impression being wide, and not that of the true form of a projectile head.

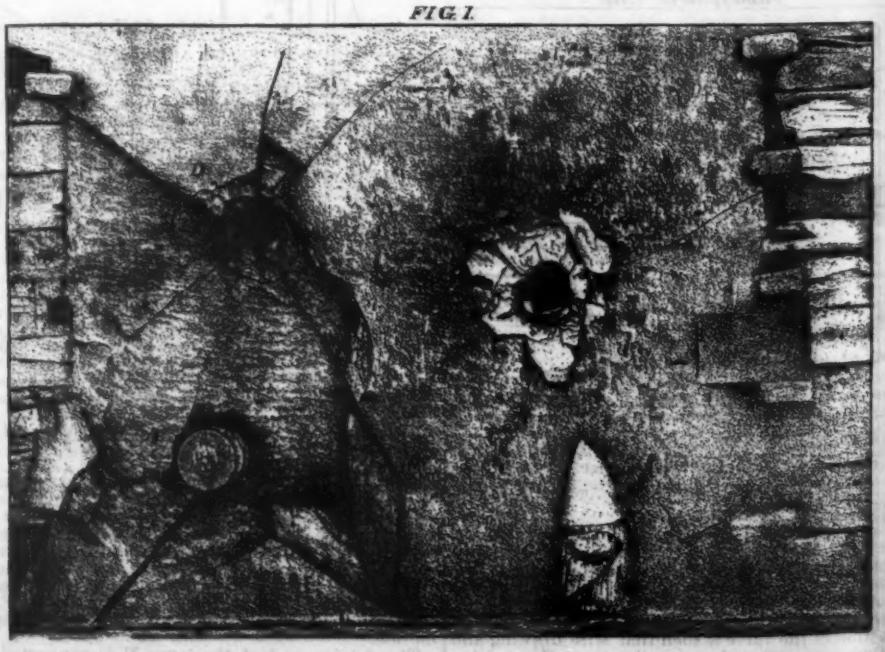
The 24 cm. projectile has, undoubtedly, behaved well. As we have before had occasion to notice with Krupp projectiles, the perforation is decidedly in excess of what could be expected. The plate is apparently a very good one, not only as to the manifestation of any one good quality, but as to the balance of them, for while it has had sufficient hardness to break the 24 cm. shell—to say nothing of the other, which we think has been broken or set up at D—it has sufficient toughness to crack but little when completely perforated at B.

The wrought iron plate would of course have been altogether deficient in resisting power had it been attacked directly by the guns, as fired above; the projectiles were therefore fired at an angle of 65 deg. with the face of the plate, with the following results:

The 28 cm. (11 in.) gun projectile entered and buried itself in the plate, turning slightly from the angle of incidence toward the normal or direct line—see A, Fig. 2, which is a front view of the wrought iron Cammell 15·5 in. plate after attack. The 24 cm. (9·45 in.) projectile passed clean through the target, breaking up, however, the fragments all lying beyond the target. The target itself was torn and the supporting angle plates broken—see B and D, Fig. 3, which shows the back and supporting framework of Cammell wrought iron plate target at Meppen, with the hole made in the plate and frame by Krupp projectiles. Fig. 2 shows the shot hole at B and the shot point at G. We have no information as to the unlettered shot holes. Fig. 3 shows the back and supporting structure of target. As to the above trials, the Krupp projectiles, as well as the plates, appear to be excellent.

On the whole, we are inclined to think that Krupp has increased the hardness of his shot, and that they have rather less tenacity than some we have seen of his and some of other makers recently in this country. It would be difficult to suggest any improvement in the relative powers of hardness or tenacity in either plate or shot from the results before us. We are generally inclined to think that plates must be made harder than

FIG. 1.



STEEL-FACED AND WROUGHT IRON TARGETS AT MEPPEN.

we have latterly seen them, when projectiles have passed intact through them, making clean holes. This we think argues too soft a plate.

The passage of a shell containing explosives—such have latterly replaced powder—into the interior of a ship would be so intolerable a thing, that we should prefer the plate to crack and heat to a considerable extent rather than allow the shell to get through intact. A broken plate may be held up and still offer a considerable measure of resistance if well bolted on, and it is hardly likely that a second shot will strike close to the first.

At all events such a risk must be run rather than allow the passage of a shell filled with blasting gelatine or any similar compound into the interior of a ship. Here, however, it is to be noticed that the projectile which perforated was in each case broken up. This we are a little surprised at, and question if Krupp is quite satisfied with the result. Had it only occurred in the case of the compound plate, we might have attributed the result to the special hardness of the face, but it occurred also in the case of the wrought iron, although, we admit, at an oblique angle, and perhaps fracture may be due to the second blow on the frame. On the whole, we question if the projectiles have all the tenacity that might be given with advantage. Krupp may reply that more tenacity would involve a slight loss in hardness, such as would have prevented the complete passage of the 24 cm. shells; and we should admit the answer to be good, seeing that the perforation is in excess of what we should calculate it. While we are inclined to question, then, if tenacity is not at present the weak element in the projectiles, we cannot say whether an improvement in this direction would not involve the sacrifice of hardness to an extent that may be mischievous, especially if plate faces become harder, as we expect eventually to be the case. We have, however, to record a further trial of 21 cm. projectiles fired at the same plate in March last.

FIG. 2.

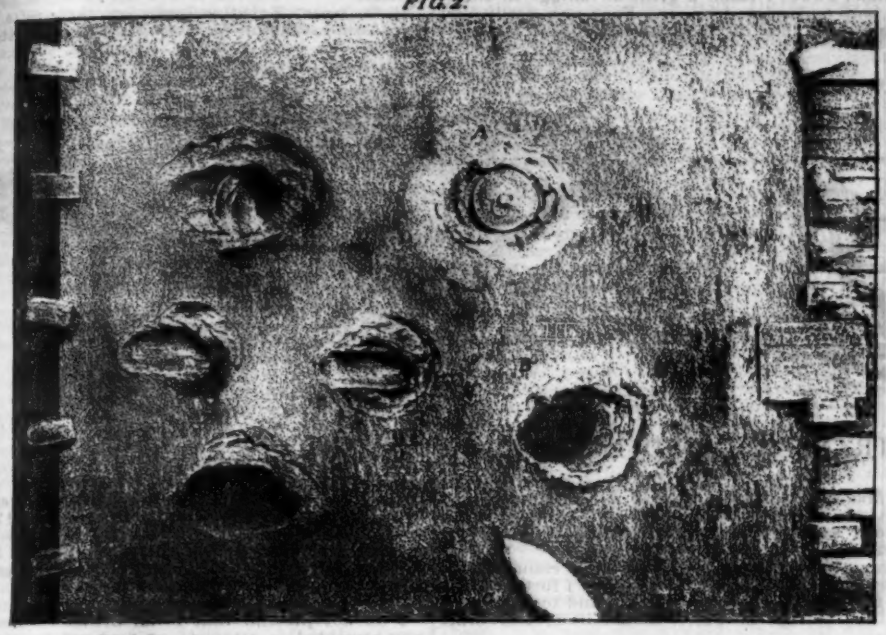


FIG. 3

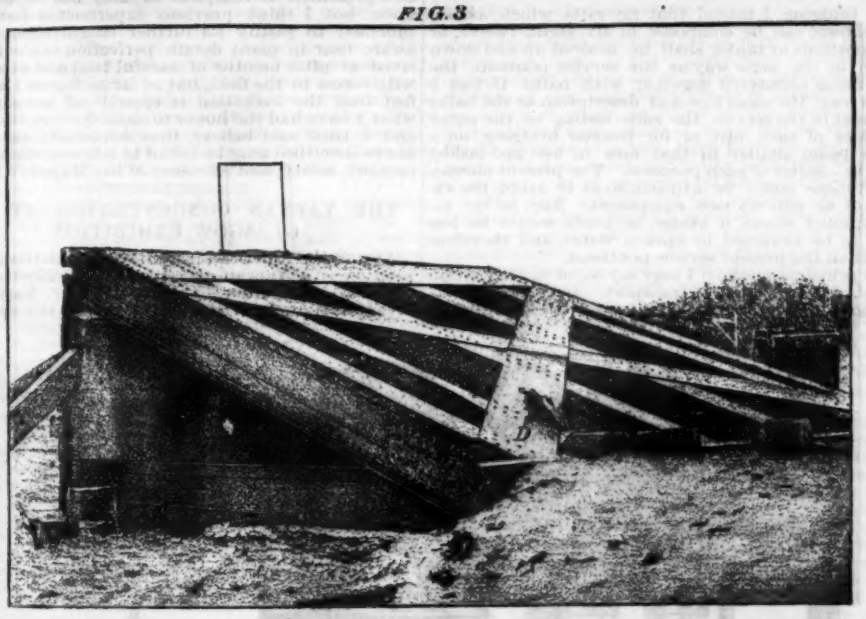
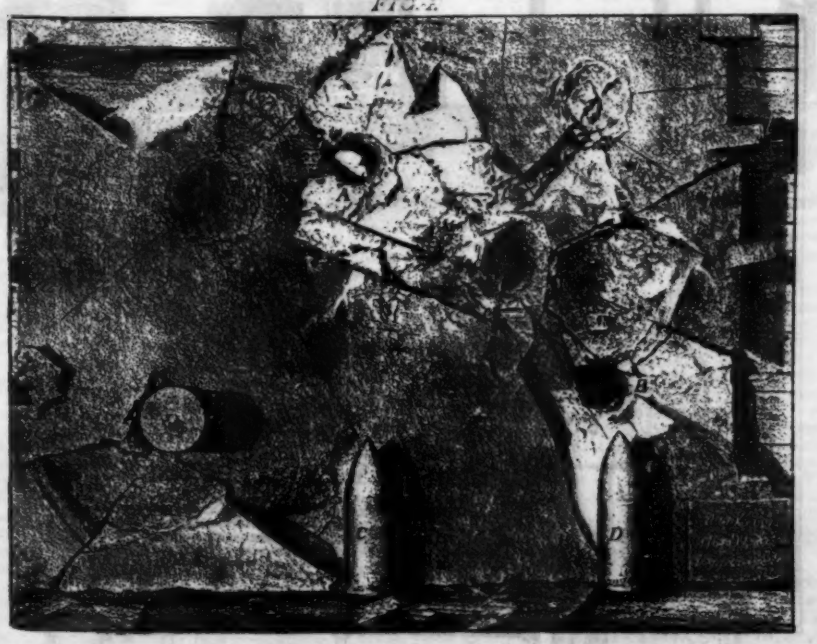


FIG. 4.



STEEL-FACED AND WROUGHT IRON TARGETS AT MEPPEN.

On March 3 last, Messrs. Krupp made further experiments with new special armor-piercing steel projectiles of 3¼ calibers length, fired against the same Cammell, 39·5 cm. (15·5 in.) thick, with 20 cm. (7·87 in.) oak backing and skin, from the 21 cm. (8·26 in.) gun. The weights of the two projectiles fired were 128·3 kilog. (304·9 lb.) and 127·8 kilog. (306·8 lb.) The striking velocities of the shot were, in two rounds fired, 550·2 meters (1805·2 ft.) and 551·2 meters (1808·4 ft.) respectively. The striking energy of the projectile with the higher velocity was 6,889 foot tons, and the perforation 16·98 in. of iron, or 13·58 in. of steel or steel-faced armor, or very little in excess of that of the 28 cm. (11 in.) projectile fired in the previous experiments.

Nevertheless, both projectiles passed completely through shield and backing in the shot holes marked A and B, in Fig. 4, which is a front view of Cammell's steel-faced 15·5 in. plate after attack by 28, 24, and 21 cm. Krupp guns. The projectiles themselves passed on to distances of 40 meters (43·7 yards) and 670 meters (732·7 yards) respectively. The plate behaved well, showing but little cracking, although it had now been severely attacked, as may be seen in Fig. 3. The recovered projectiles are shown below their respective shot holes, and are in excellent condition, being without cracks and but very slightly set up.

We think that the success which we could not say was completely achieved in the December experiment was undoubtedly attained here, seeing that the projectiles have both perforated a greater thickness of plate than would be calculated, and also having been uninjured. Such behavior would, we think, for reasons given above, compel us to adopt still harder faces to our plates, even at the cost of much cracking and fracture.—*The Engineer.*

[JOURNAL OF THE ROYAL UNITED SERVICE INSTITUTION.]

IMPROVED TRANSPORT AND PONTOON EQUIPMENT.*

By Lieutenant E. S. COPEMAN.

THE intention and design of this invention is to provide a light form of pontoon equipment which can also be utilized for other purposes, such as the transport or storage of water, ammunition, and other stores, when not actually required for pontooning purposes.

My invention consists of a light cart (see cut), which carries a galvanized steel tank covered in at the top, supplied with two manholes, and divided down the center by a water tight compartment. The tanks are made in two shapes. Those which form the ends of the pontoon are rounded at one end like the bow of a barge, and the center tanks have square ends. The sizes and dimensions will be given hereafter.

The carts which carry these tanks have long straight shafts running from the extreme rear of the carts, and are furnished at each end with rings.

When a raft is formed of six carts and tanks, the tanks are placed in two parallel lines end to end, forming two pontoons, each consisting of three tanks (two curved-end tanks and one square or middle tank). The three tanks forming each pontoon are securely attached together, end to end, with double hooks below water line, and with rings and wedges at the top. The wheels are then removed from the carts, and the bodies of the carts placed side by side across the two pontoons, the shafts being securely lashed down to the outer edges of the pontoons, and forming the transoms which hold the pontoons together. A folding flap of the floor of each cart is then thrown over, and covers a part of the open space between the shafts, the flap also resting upon the inner side of the opposite pontoon. The carts are placed alternately, three pairs of the shafts pointing to the right and three to the left.

The bodies of the carts so placed form a complete platform down the center of each raft, the shafts underneath holding the two pontoons together, and supporting the platform.

A strong protection along the sides of the roadway, down the center of each raft, can be formed of the front and tail boards of the carts and the wheels if necessary.

The size and weight of the tanks and carts would of course depend upon the special purpose for which they were intended, but for the present I have designed them for a light equipment, such as that first recommended by Major G. S. Clarke, R.E., in his report on "Pontooning operations of the Austrian army, September, 1886."

Major Clarke says: "The requirements of European warfare seem to involve—

"1. A light equipment, able, without difficulty, to accompany cavalry and horse artillery in rapid movements; so as to be available for employment with an advanced guard, a reconnaissance, or a cavalry raid. Such an equipment should provide a bridge of moderate length to carry horses in single file; but should be capable of forming transporting rafts to carry a horse artillery gun."

2. He next describes a heavy equipment for bridging such rivers as the Danube, with which I do not propose to deal now, further than to say that, if my pontoon is superior to existing systems as a light equipment, it would only need to be made of heavier metal and larger size to meet any other requirements.

The dimensions, etc., of the tanks I have designed for a light equipment are as follows: Width, 3 feet; depth, 2 feet, with a coaming round manholes of 6 inches. The end tanks 5 feet 6 inches long, with a sheer of 6 inches toward the end; the middle tanks 5 feet long.

The average weight of each tank is about 2 cwt. Each pontoon, therefore, of three tanks, weighs 6 cwt.,

* Read at meeting on March 21, 1888.

and has a maximum buoyancy of 6,000 lb. and an available buoyancy say of one-half, or 3,000 lb.

A raft composed of two pontoons, each of three tanks, covered and connected by six cart bodies, would weigh altogether less than one ton, and would have an available raft buoyancy of 6,000 lb.—sufficient to carry thirty-six men or three horses.

The actual displacement of each tank is about 1,800 lb., giving an available buoyancy of about 1,000 lb.

A raft of eight portions instead of six would increase the length to 21 feet, and the available buoyancy to about 8,000 lb., sufficient to carry about 50 men or five horses, or a 9 pr. gun and limber weighing 3,500 lb.

The size of the rafts might be increased, by the insertion of extra middle tanks, to 12, 14, or 16 portions.

Our present service pontoon is 21 feet 7 inches long, weighs 9 cwt. 2 qrs., or 1,964 lb., with a displacement of 13,350 lb.

The Austrian pontoon is also formed of metal tanks or boats, attached together in much the same way as my own invention, but not covered in at the top. The end tanks or portions are 13 feet 6 inches long, and the center portions 11 feet 4 inches long. They are all 6 feet 2 inches wide and 2 feet 6 inches high. Three portions, forming a boat, weigh 2,763 lb., or 1 ton 4 cwt. 75 lb. Each portion has available buoyancy sufficient to carry ten men or one horse.

This, however, is a very heavy equipment, suitable for bridging large rivers with strong currents, but very heavy for transport.

Major Clarke in his report says: "The boats are very strong, row well, are extremely manageable, and remarkably steady under a load. The power of being able to make up a boat of any length has many conveniences. The coupling of boats end to end further allows rafts to be constructed in great variety and form, and these rafts can not only be handled with little difficulty, but are particularly well suited for embarking and disembarking horses and wagons. Our instructions provide for the formation of no rafts other than mere lengths of a bridge, and it is not easy to see how such an operation as that of the 31st August, when an advanced guard of 800 men and 68 horses were thrown across the Danube in rafts, could have been carried out with our equipment. There are various occasions on which it is very desirable to be able to take the load upon the gunwales of the boats, instead of on the central saddle. It is a special advantage with the 'half-decked (Austrian) raft' that horses can be walked straight on and off. The desirability (he says) of being able to arrange easily for raft transport has perhaps been too much lost sight of."

He concludes: "If at any time it should be necessary to devise a new system for use—as in India—on large rivers with swift currents, it is for consideration whether the Austrian form of boat, lightened as he suggested, would not be more suitable than our weaker, less roomy, and perhaps less manageable pontoon."

In June, 1884, I supplied the War Office with a metal pontoon raft of about the same dimensions as the one I have just described, and I had the honor of attending and conducting the experiments at Chatham, after taking the raft round from London by water to within a few miles of Chatham in tow of a steamer, and sailing it the rest of the way.

The Royal Engineer committee reported as follows: "The buoyancy of each boat (three tanks) is about 6,000 lb., and the raft, complete with its gear, took forty-two men, say 3 tons, with a freeboard of 6 inches. 'The stability of the raft was tested by moving twenty men as rapidly as possible from side to side—the results were very satisfactory.' 'It was compared with a Blanshard and service pontoon as regards rowing, and was inferior to both in speed, but somewhat easier to steer.' The raft is, upon the whole, a neat and efficient structure."

The report then enumerated certain defects in the pontoon which was then submitted, all of which I claim to have overcome in the present design, and also in the question of speed I have made an improvement, by keeping the pontoons further apart.

The committee conclude by stating: "The rafts, though not suited for bridging purposes, are well suited for use in broken water or open sea, their great buoyancy and stability, and the impossibility of swamping them, being all in their favor."

I had also the honor of sending some smaller tanks and carts to the Soudan during the late expedition, but I understand the carts were sent to one place and the tanks to another, and I have never been allowed to see any report which may have been sent home, or to know anything further than that they were not adopted.

A cart and tank similar to those I supplied for that expedition (with the exception of the wheels) will, I hope, be ready for members to inspect on leaving the Institution, after this paper has been read. This cart does not comprise the improvements I have designed for making the body of the cart form the superstructure of the raft or bridge, but it will be sufficient to test its capabilities as a water cart, and by way of experiment, Colonel Cantlon, of the 2d London Rifles, has kindly arranged to take it down with his regiment to Dover, at Easter.

I trust it may be found possible for other volunteer regiments to assist in carrying out the experiment by adopting one or more of my carts as part of their transport equipment, so that by joining six or more of them together, the experiments with their use as rafts may be carried on, and lead eventually to their experiment and use in the regular army.

In splitting my pontoons up into tanks, each weighing under 2 cwt., I claim a great advantage in transport, both on land and by sea. Four men easily (and two men for a short distance) can carry one of my tanks past almost any obstacle, such as a Nile cataract, and place it in its position again in the raft, while a service pontoon can only be carried for a short distance by eighteen men.

I hope I have now established some claim for the utility of my invention as a raft, but I further claim that it is also available for bridging and for the transport and storage of water, ammunition, and other stores.

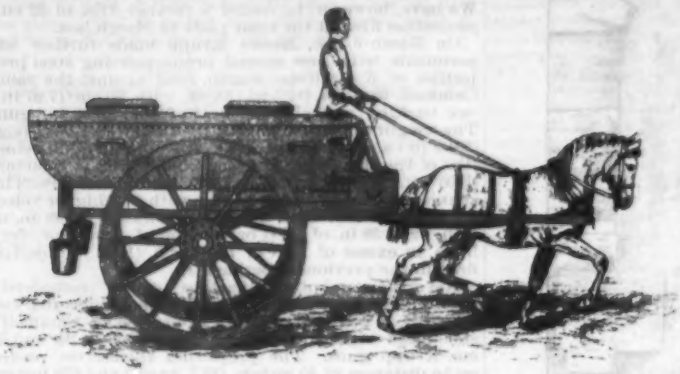
For bridging, I intend that my rafts, which, as has been shown, can be composed of six, eight, twelve, or more portions or tanks, shall be moored up and down stream in the same way as the service pontoon, the rafts being connected together with balks 15 feet 9 inches long, the same size and description as the balks now used in the service, the ends resting on the outer gunwales of each raft, or, for heavier bridging, on a saddle beam similar to that now in use, and lashed down the center of each pontoon. The present chesses and ribbons could be utilized, so as to avoid the expense of an entirely new equipment. And, as the report quoted shows, a bridge so made would be less liable to be swamped in broken water, and therefore safer than the present service pontoons.

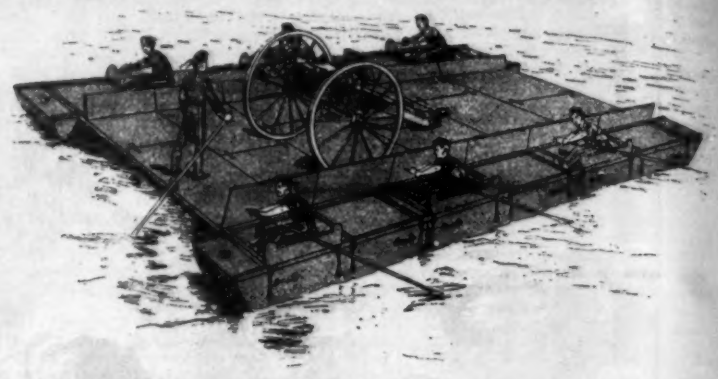
The principal merit, if I may say so, of my invention consists in its facility of transport. In the first place, the carts and tanks are so adapted to the ordinary transport requirements of an army that if a certain number of these carts were attached to each battalion as part of their transport, an efficient raft or pontoon bridge would always be within reach of every regiment whenever it might be required, and I need hardly, in the presence of the members of the Royal United Service Institution, enlarge upon the advantage this would give to any force employed either at home or abroad.

In the recent Egyptian campaign, these rafts would have been invaluable for towing stores along the canals, as they draw only 18 or 20 inches of water; also for conveying stores and troops from on board ship to a shallow beach.

In the Soudan they would have been useful for the carriage of water, as each tank holds 180 gallons, and when full does not, with the cart, exceed 1 ton in weight, being the load for an ordinary horse.

I do not pretend that in all details the design as now presented is complete or may not be improved upon, but I think previous experiments have been sufficient to justify its further consideration. I am aware that in many details perfection can only be arrived at after months of careful trial and experiment with forces in the field, but as far as it goes I am satisfied that the invention is capable of accomplishing what I have had the honor to claim for it in this paper, and I trust and believe that eventually the system above described may be found to add something to the comfort, safety, and efficiency of her Majesty's forces.





IMPROVED TRANSPORT AND PONTOON EQUIPMENT.

THE YARYAN CONCENTRATOR AT THE GLASGOW EXHIBITION.

AMONG the American inventions at the Glasgow Exhibition is a Yaryan concentrator, an illustration of which we give from *Engineering*. Mr. Yaryan, the inventor, is an American engineer, and the apparatus

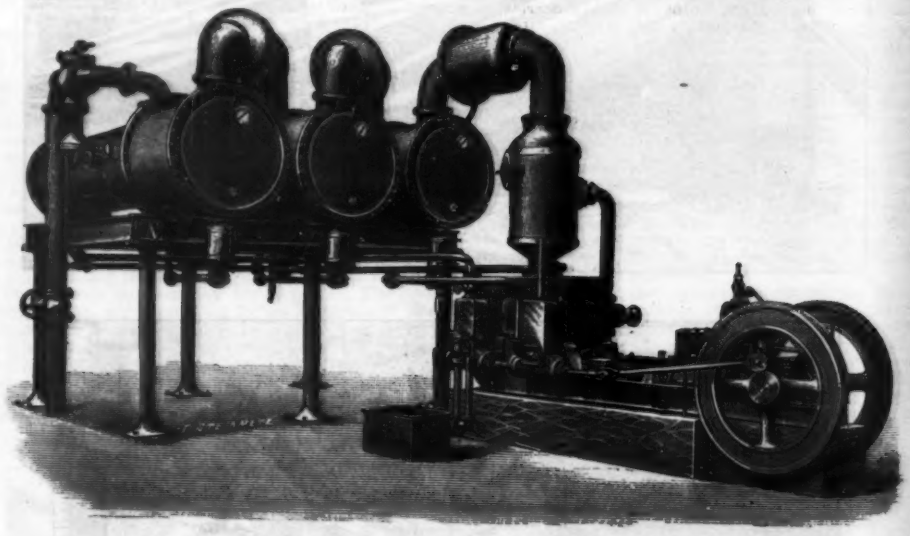


FIG. 1.

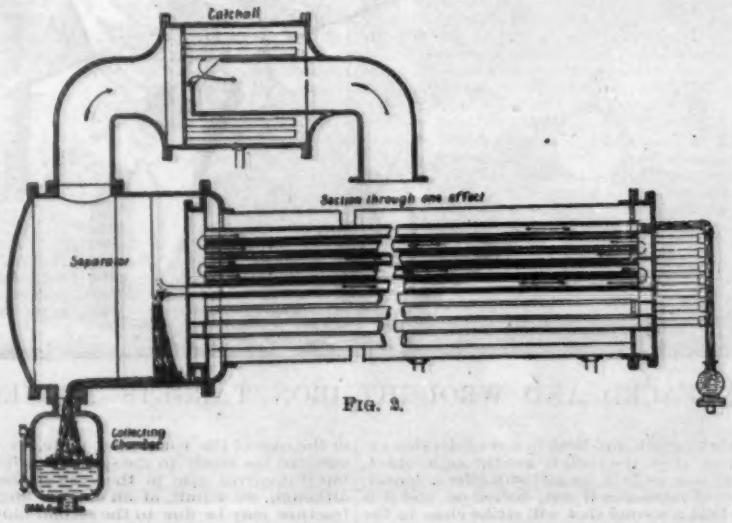


FIG. 2.

THE YARYAN CONCENTRATOR AT THE GLASGOW EXHIBITION.

has been already largely adopted. In the manufacture of sugar on the plantation, as well as in the process of refining, concentration is one of the leading operations, and the fuel for performing it forms one of the chief items of expense. At present, in well-equipped factories, the work is always performed by a double or triple effect apparatus. This contains a large heating surface in steam-heated tubes, the space in or around which is filled with the liquor under treatment. The first pan is heated with steam at about 10 lb. pressure, generally the exhaust steam from various engines, the second by the steam given off from the liquor under treatment in the first, and the third by the steam from the liquor in the second. The result of this action is an economy of steam, and therefore fuel, represented theoretically by the number of pans. Thus, in a double effect one-half, and in a triple effect one-third of the fuel is theoretically needed, as compared with doing the work in a single pan at one operation.

The Yaryan concentrator also acts on this multiple effect principle, but its special feature is that the space in or around the heating tubes, as the case may be, is not filled with the liquor, but only with a mixture of the liquor in a finely divided state and the steam rising from it.

The general arrangement of the apparatus exhibited at Glasgow is shown in Fig. 1. As will be seen, it consists of three horizontal vessels mounted on a light staging. It is provided with a condenser and pumping engine for maintaining a high vacuum in the last pan, and the engine is also provided with small pumps for feeding the liquor into the first pan, and withdrawing it, after concentration, from the last.

The action of the apparatus will be understood from the diagram, Fig. 2, giving a simplified section through one of the pans and "catch-alls." The heating tubes, surrounded by steam, are divided into units or sections, known as "coils," and consisting of five tubes coupled at the ends so as to form one passage. One of these "coils" is shown in the illustration. Its action may be taken as typical of that of all the coils, in the pan, of which there may be any number proportional to the work to be done. The liquor enters the first tube of the coil in a small but continuous stream and immediately begins to boil violently. It is thus formed into a mass of foam, which contains, as it rushes along the heated tubes, a constantly increasing proportion of steam. As the foam and steam cannot escape by the inlet end of the coil, and as steam is being continually formed, the mixture is propelled forward at a high velocity, and finally escapes from the last tube into an enlarged end chamber, known as the separator. This is provided with baffle plates against which the mixture of steam and liquor impinges on issuing from the tube. The liquor falls to the bottom, while the vapor passes on to heat the next pan.

The arrangement described is said to give an almost perfect separation of the liquor and vapor, but to make doubly sure and to avoid the chance of losing any sugar, the vapor is next passed through the special form of catch-all shown in the illustration. This is also a part of Mr. Yaryan's invention. Here the vapor is divided by tubes into a number of small streams, each of which impinges against the end wall of the chamber, giving up any drops of liquid carried over. The vapor itself escapes by the central pipe. This catch-all is found in practice to prevent any detectable loss, even when used for liquors far more liable to foaming than those to be dealt with in sugar manufacture.

The advantages claimed for the Yaryan apparatus are many and important. The duty of each square foot of heating surface is twice that which can be obtained in apparatus worked in the ordinary method. There is only a small quantity of liquor in the apparatus at any one time, and the circulation is rapid and compulsory. These are both very important points, seeing that the action of heat on sugar is injurious in proportion to the time during which it is applied, as well as to the intensity of the heat. The apparatus is found in use to be practically automatic and requires the minimum of attention. It can be started and stopped in far less time than that needed with the older apparatus, which will contain hundreds or even thousands of gallons of liquor.

At the present time Messrs. Mirrlees, Watson & Co. are busy in executing orders for the Yaryan machines for sugar purposes. At the same time large numbers are being made for use in chemical manufacture, paper making, and other industries.

PHOTOGRAPHIC NOTES.

Printing and Toning.—Says the *British Journal of Photography:* In most instances ready sensitized paper contains a considerable amount of free acid of an organic nature, such as citric or tartaric, which, if left in the paper, will, under ordinary conditions, materially interfere with the operation of toning. Some imagine, in washing out the free nitrate of silver previous to toning, that the whole of the acid is removed also. This, however, is not always the case, and for the following reason. The majority of the commercial sensitized papers contain much less free nitrate than those of home preparation. Hence it may be entirely removed while a considerable amount of the acid still remains. This may be easily demonstrated by pressing a piece of litmus paper in contact with a print after the washing waters have ceased to show signs of "milkiness"—the usual test for the removal of the free silver salt.

A short time back we received a sample of paper which the sender asserted could not be toned. This paper, we found, was intensely acid, and contained but a very small proportion of free nitrate of silver, which latter was almost entirely removed after a short immersion, even in the first washing water, though much of the acid remained. It also printed a bright red in the frame. As our correspondent had said, the prints could scarcely be toned at all; however, some of them, after the silver had been removed, were soaked for a quarter of an hour or so in a dilute solution of common washing soda and afterward rinsed in water. After this treatment the prints toned easily to a deep brown, and eventually turned out very good pictures. As a rule, whenever the paper prints unduly red in the frame and a difficulty is experienced in toning, matters are much improved by the soda treatment. Indeed, we know some who make it a rule always to immerse their prints in a weak solution of carbonate of soda—a crystal about the size of a small walnut in a quart of water—prior to toning. Then if the paper contain any citric or tartaric acid, this will of course be neutralized and converted into the citrate or tartrate of soda, as the case may be. It may be mentioned that one of the earliest formulæ for an alkaline gold-toning bath contained the citrate of soda, as its presence was said to be conducive to rich, purple colors.

A very fruitful source of failure with the novice in printing is the toning bath itself. Often it does not contain a particle of chloride of gold, when it is really supposed to be rich in the precious metal, simply because less than, may be, a sixth of the theoretical quantity of paper it was capable of toning had been used. There are many reasons for this; one—though perhaps a minor one—is that much of the chloride of gold sold in tubes contains far less than the theoretical quantity of metal.

Many amateurs employ the acetate toning bath, and when they mix up a fresh one make it very concentrated, adding the whole tube of gold in the first instance, and often use it in this state, and afterward return it to the stock bottle for future use, a system to be deprecated. Often after one or two batches of prints have been toned in such a solution, although there ought still to be sufficient gold left to tone many times the number of prints treated, it is found to have lost all toning action, owing to the gold having become precipitated. A very general cause of the decomposition arises from the solution having been put into a vessel that was not chemically clean. We have frequently known a tyro to employ the same dish for toning that had been used for developing or fixing negatives, and after only a perfunctory washing. In such a case there is little wonder if, after a short time, the solution becomes decomposed. Unfortunately, the manipulation of dry plates has not engrafted into the minds of the majority of modern amateurs the absolute necessity for chemical cleanness in all photographic operations that the old wet collodion process did. Hence the reason for many of the failures met with in printing. There is no doubt whatever that some of the commercial sensitized paper contains matters that act injuriously on the bath, as we have known instances of a spontaneous deposition after the bath had been once used, which could not in any way be attributed to the above cause.

Many beginners get into trouble through employing the toning bath too strong and immersing too many prints at a time. If the acetate bath be made in the concentrated form, as it often is, say, one grain of chloride of gold and thirty grains of acetate of soda to the ounce of water, an ounce of this solution diluted with eight or nine ounces of water will be sufficient to tone a number of prints, equivalent to one sheet of paper, to a deep color, and will be a convenient strength to employ. After use the solution may be poured into a bottle kept specially for the purpose, then, when a fresh lot of prints have to be toned, some more of the strong solution is added, in the proportion of an ounce to each sheet of paper. By this system of working the stock solution never gets contaminated with any deleterious matter the paper may contain. If any decomposition takes place in this solution, it will be quite clear either that the water with which it was mixed or the acetate was impure, or that the bottle was not chemically clean. After a toning bath has been used, it should not be exposed for any length of time to a strong light, as that would cause a reduction of the gold.

Dismissing the acetate bath, we shall now refer to some others which can be prepared and used at once, and it may as well be mentioned in passing that the majority of them will keep but an hour or two after they are once mixed. Therefore, when making up such solutions, it is always desirable to first consider the number of prints to be dealt with, and then only compound sufficient for the work immediately in hand. This may easily be estimated by taking one grain of gold as being equivalent to each full sized sheet of paper to be toned. Of course, if only a light reddish brown be desired, less gold with most papers will suffice. Whichever of the baths to be described be adopted, it will be convenient to always keep the chloride of gold in a stock solution, say, of one grain to the drachm of water. This will be secured by dissolving the contents of a thirty-grain tube in thirty drachms of distilled water.

First, there is the carbonate of soda bath. This, at one time, was much used by professionals. It is easy to prepare and will yield good purple or black tones with suitable negatives and paper. When, however, the toning is carried to the black stage, there is a greater tendency to coldness than with some other solutions. The solution is prepared by simply dissolving four grains of bicarbonate of soda in eight ounces of water, and adding one drachm of the standard solution of gold. This bath must be prepared within an hour or so of its being used.

A very simple solution, and one well suited to the amateur's use, is the borax bath. This is made by dissolving forty grains of borax in eight ounces of hot water, and adding a drachm of the gold solution. As soon as cold the bath is ready for use. This yields deep, rich, pleasing purple-brown tones. Then we have the "phosphate bath," a very simple yet efficient one. It is composed of phosphate of soda, half a drachm, chloride of gold, one grain, in eight ounces of water. This and the borax bath both keep somewhat better than the carbonate bath, but they must be used within two or three hours of their preparation. The "tungstate bath" is a good one and easily prepared, all that is necessary being to dissolve about twenty grains of tungstate of soda in eight ounces of boiling water, and add one drachm of the gold solution, the bath being ready for use as soon as it has become cold.

The "lime bath," at one period, met with considerable favor among a large number of artists when black tones were desired. It is prepared as follows: One grain of chloride of gold and ten grains of carbonate of lime are mixed with eight ounces of water; then two minims of a saturated solution of chloride of lime are added and well shaken. If the bath be made with boiling water, it can be employed as soon as it has attained the ordinary temperature of the atmosphere, by which time the excess of carbonate of lime will have subsided to the bottom of the vessel, though it will work still better after twenty-four hours' keeping. If the solution be made with cold water, it will not work satisfactorily unless it be kept for several days. With this bath considerable overprinting is necessary, as the prints reduce very much in the toning.

Here is another lime bath which is well suited to the requirements of the amateur, inasmuch as it can be prepared and used at once, or it will keep for a considerable time. It does not, like the other solution, necessitate more overprinting than most baths, and it yields much warmer tones when the action is carried to the deeper stages. In the preparation of this it is convenient to have three stock solutions. One, the standard solution of chloride of gold; another of lime water, made simply by shaking a handful of slaked lime in a Winchester quart bottle of water and allowing the excess to subside; the third solution is an ounce of *dried* chloride of calcium dissolved in thirty ounces of water. The bath is prepared as follows: One drachm of the gold solution is added to, say, two or three ounces of water, and a piece of blue litmus paper dropped in, which will be immediately reddened. Next, lime water is added until the blue color is restored; then half an ounce of the chloride of calcium solution is poured in, and the bulk made up to eight ounces with water. The solution is then ready for use. This bath keeps well, and may, if desired, be made up in a concentrated form like the acetate bath, though we prefer to mix it up as required.

To summarize, each of the baths now alluded to is a good and reliable one. They each yield somewhat different results, and the difference will be more manifest when the toning is carried on to the purple or black stage than when it is arrested at an earlier period. Any solution that will produce black tones will also yield brown ones if the prints be taken out at the proper time, though all baths will not give black colors that will produce good browns. Again, most baths will behave differently with different samples of paper. But, as we have often said before, the obtaining of deep purple and black colors is really more dependent upon the character of the negative and the paper than upon the composition of the toning solution.

In all the formulæ just given, it will be noticed that the proportion of one grain of the chloride of gold to eight ounces of solution is adopted, and this strength should never be exceeded. As a rule, slow toning produces better and more equal results than rapid toning. Also, slowly toned prints undergo less change in the fixing bath. It is always advisable with most of the ready sensitized papers to thoroughly eliminate the acid, either by washing or neutralization, before putting the prints in the toning bath. Free acid in the paper retards toning and conduces to mealiness.

Preparing Glass Plates for Use in the Wet Process.—Mr. T. N. Armstrong, in the *British Journal of Photography*, tells his method as follows: I obtain a quantity of thin white 5×4 glass from a dealer; as a rule, when bought in packets of three dozen or so the packets have not been previously opened, and are, therefore, quite free from thumb and finger markings with their attendant greasy spots, which are at all times difficult to remove. Should any glasses have such marks, I reject them entirely. The glasses are then taken to a water tap, and before commencing operations I take about fifteen grains clear gelatine and dissolve it in twenty ounces of hot water. When cold run it through a clean pocket handkerchief to filter into a clean jug. We are now all ready to go ahead and prepare a stock of glass that will keep for any length of time, will always be as available as a bromide dry plate—in fact, in my opinion, much more easily worked. I then take a coarse towel and fold it into a long, thick fold, which I spread along some convenient support such as a wall or long box. The glasses are then well washed under the tap till the water runs freely over them, and while still wet a pool of the gelatine solution is poured on them, and allowed to flow over the whole surface of the plate. This I do twice; the first application removes all the water, and the second application of the gelatine solution completes the operation. The glasses are then reared up on end face to the wall on the towel to drain, which they will do in a short time, and in fine dry weather will be quite dry and ready to be stored away in their grooved boxes in about a couple of hours. *Beware* of dust, however, in every step you take. In placing the glasses in the grooved boxes I always keep the gelatinized side facing the right hand. There is then no mistake made when pouring on the collodion. A stock of glasses thus prepared robs the wet collodion process of its greatest drawback, and turns an otherwise messy and troublesome operation into one of pleasure.

Removing Gelatine Films from Glass.—According to S. L. Dobie, it is only necessary to soak the plates in a strong solution of washing soda for three hours at a temperature of 60° Fa. The film will loosen first around the edges and may then be easily peeled off.

If it is desired to preserve the film, it should be hardened by immersing for a few moments in an alum bath.

Blue Prints.—In the *Moniteur de la Photographie* M. Gauthier-Villars gives the following formula for the conversion of the blue color of cyanotypes into brown:

I. *Solution for the Preparation of the Paper.*

Potassium ferritartrate	15 grammes.
Potassium ferridcyanide	12 "
Distilled water	250 c. c.

II. *Solution for Bleaching the Prints.*

Ammonia (22°)	100 c. c.
Distilled water	900 "

III. *Solution for Coloring Brown.*

Tannin	10 grammes.
Distilled water	500 c. c.

The blue prints are first well washed and then dipped into solution No. II. until the image is completely bleached. It is then washed again and immersed in the tannin bath solution III., where it is left until it has assumed the desired tone, which may not be until after twelve hours. If at the end of this time the desired depth shall not yet be attained, a few drops of ammonia should be added. Finally, the print is washed with plain water. To blacken blue prints Mr. Roy's method is recommended, bleaching yellow in a solution of four grammes caustic soda to 100 c. c. water, then blackening in a solution of four grammes tannin to 100 c. c. water.—*British Journal of Photography.*

BELL'S WATER JET TELEPHONE.

THE discovery that the electrical resistance of a jet of conducting liquid is influenced by mechanical or acoustic vibrations is due to Mr. Chichester A. Bell, who brought this subject before the Royal Society in May, 1886. The paper was on the sympathetic vibrations of jets, and it is on some observations recorded in this paper that the water jet transmitter is founded. We take the following from *Industries*. When a jet of water issues from a narrow orifice, it gradually becomes discontinuous, and breaks up into drops, as shown in the diagram on the left hand side of Fig. 1, which is taken from an instantaneous photograph. The other diagram in Fig. 1 shows a jet of water falling from a tube fixed to a board on to a membrane of stretched India rubber, forming a cap to a brass tube which can be raised or lowered by sliding in a large tube resting on a heavy stand To the upper tube is attached laterally a funnel of vulcanite, which magnifies the air vibrations. With this apparatus either mechanical or sound vibrations communicated to the jet are reproduced with great loudness and distinctness, both of which increase up to a certain point when the length of the point is increased. After passing the point the sound still continues to increase in loudness while losing its distinctness, until ultimately it becomes a mere unmusical roar, and it will then be found that the jet has become discontinuous.

When the board to which the jet is attached is scratched with the finger, or when a watch is held in

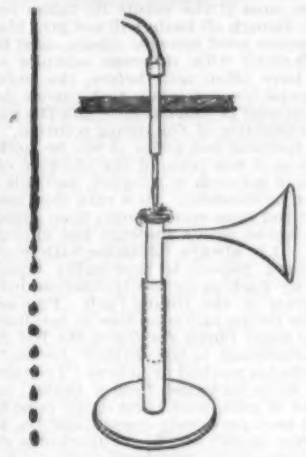


FIG 1

contact with the jet tube, the sounds produced are loud enough to be heard throughout a large hall. If the jet is spoken to, or whistled to, it is visibly thrown into vibration, and if attached to a sounding board, the sounds are distinctly reproduced. If the jet is allowed to fall upon the top of a small vertical plug, as shown in Fig. 2, it spreads out into a nappe, and Mr. Bell found that this nappe was capable of responding to the vibrations in a similar way to the jet itself, and it is this property which is utilized in the construction of the water jet transmitter.

In this instrument a jet of conducting liquid forms part of an electric circuit containing an ordinary telephone receiver. The nappe formed by the impact of a steady jet retains a constant diameter, but when the jet is thrown into vibration, the diameter of the nappe undergoes periodic changes. The result is a variation of electrical resistance, which Mr. Bell considers to be due in part to the changes in diameter, and in part to changes in the contact resistance, arising from the motions of the particles of liquid; so that the current passing through the circuit undergoes corresponding continuous variations in strength, as in other forms of

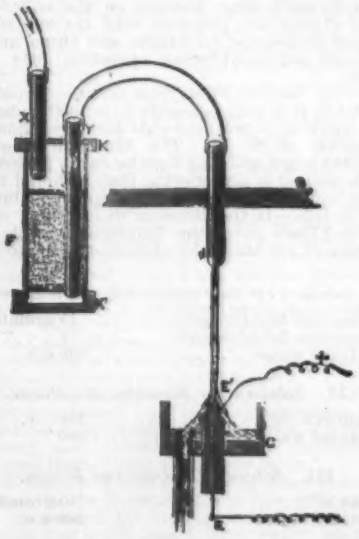


FIG. 2.

telephonic transmitters. The simplest way of passing a current through the nappe consists in allowing the jet to strike normally upon the exposed end of a platinum wire embedded in an insulator which is impervious to, and is unaffected by, the liquid employed, surrounded by a platinum ring which comes in contact with the outer portion of the nappe. The most suitable liquid is water acidulated with about $\frac{1}{15}$ of its volume of pure sulphuric acid. The battery must be of high e.m.f., but its resistance is of little consequence, owing to the high resistance of the transmitter. The number of cells must, however, not be so large as to produce an appreciable amount of electrolytic action, as the noise produced in the receiving telephone by the escape of gas bubbles would drown the sounds due to vibratory changes in the jet.

In its original experimental form the transmitter was made as shown in Fig. 2, where the jet tube, J, is mounted in the sound board, S. The receiving surface is formed by the end, E^1, of an ebonite plug. A platinum wire, E, passes water-tight up the plug, and its upper exposed surface forms the inner electrode of the transmitter. The outer electrode, E^1, consists of a small tube of platinum foil concentric with E, and insulated from it by the ebonite. The top of the plug is turned to a smooth and slightly convex surface. The plug is screwed into an ebonite cup, C, from which the water flows off through a waste tube. F is a filter closed by screw caps, K and K^1, through the upper of which pass two tubes, X and Y, which are connected with the reservoir and jet respectively by means of black India rubber tubing. Two perforated ebonite disks are fitted within the cylinder, and the space between them is tightly packed with coarse cotton, which has been freed from grease by being soaked in a solution of caustic potash, and then thoroughly washed with dilute sulphuric acid and with water. The filter is necessary to keep back particles of dirt which might stop the orifice, and also air bubbles, the presence of which sets up vibrations and gives rise to a crackling sound in the receiving telephone.

The writer has experimented with this instrument, and found that it reproduced with perfect distinctness the voice of a person speaking in the tone of ordinary conversation at a distance of 20 ft. from the sounding board; and when the instrument was placed in a room with an open window, it reproduced the sounds of a piano played in another room, also with a window open, at the opposite side of the street. When an automatic Edison chalk cylinder receiver was used in place of an ordinary Bell telephone, the transmission of conversation and music was also very good. This form of apparatus is, however, not suitable for practical work, as in addition to its requiring separate vessels to act as reservoir and to receive the waste liquid respectively, it must be carefully adjusted before use.

A great many forms of apparatus have been devised by Mr. Bell for practical use, but it is only quite recently that the inventor has succeeded in devising an apparatus which combines simplicity and certainty of action with durability.

Fig. 3 shows the instrument with the front removed. It is inclosed in a case of teak or mahogany about 3 ft. high, and is protected in front by a cover containing a round aperture, protected by crossed copper wires, opposite the transmitting jet, and in using the instrument the mouth of the speaker is placed at a distance of a few inches from this aperture, as it is neither requisite nor desirable to have a jet as sensitive as that of the experimental apparatus previously described. The electrodes in this instrument are formed of a platinum wire passing up the center of a glass plug, and a concentric ring of fine platinum wire, glass being used instead of ebonite, on account of its greater durability. The jet and plug are contained in a glass tube attached to a wooden box which rests on the bottom of the case, and serves to receive the waste liquid. The glass plug is rigidly fixed in a vertical position, and the jet is centrally adjusted over it by means of the four screws shown at the open upper end of the tube. The filter is seen on the left hand of the jet; its exit tube has its extremity enlarged into a bell which contains the cotton, and the fibers of this are prevented from passing into the narrow part of the tube by a piece of cotton material placed at the top of the bell. The reservoir consists of a wooden box similar to the first, and placed at the top of the instrument, and it is filled by taking out a screw plug in the center of its upper side and pouring the liquid in through a funnel. The terminals of the receiving telephone are connected with the two left hand binding screws, the lower one of which is connected to one electrode of the transmitter, and the upper one to a pair of springs which make contact with the suspension lever when the telephone is removed and the hook allowed to rise. The other electrode is connected with the lowermost of the three binding screws on the right, which is put to earth through the battery. The central right hand binding screw is in permanent connection with the lever supporting the telephone and with the line, while the uppermost binding screw is connected through the call apparatus to the line, and also with a spring which makes contact with the telephone lever when the telephone is hung up.

To speak through the instrument, the telephone is taken off, but the hook end of its supporting lever is prevented from rising by means of the vertical lever shown inside the case. The handle on the right outside the case must first be depressed, when a pin on its lower end draws back the vertical lever and allows the telephone hook to rise, placing the telephone in circuit with the line. The telephone lever in rising pushes up a brass rod hinged to it, thus lifting the left hand end of the lever above the reservoir, and opening a valve which allows the liquid in the reservoir to flow down an ebonite tube on the left hand side into the filter. A second ebonite tube passes from the filter and opens into the top of the reservoir, to allow air to escape immediately if the filter has run partially dry from the instrument remaining unused for some time. The depression of the right hand lever compresses an India rubber bag shown in the center of the case, and drives air into the lower box through an ebonite tube seen on the right hand, which is provided at its upper end with a valve opening inward, and forces liquid from the lower reservoir through the other ebonite tube on the right hand into the upper reservoir. The quantity of liquid pumped up by one depression of the lever amounts to only a few ounces, and is sufficient for about seven minutes' conversation. As the average length of telephonic conversations is less than this, there will usually be enough liquid in the upper reservoir even for conversations exceeding this time. Fresh liquid can, however, be pumped up during use without interfering with the conversation. The object of the central lever, which keeps the telephone out of circuit until the pump lever is depressed, is to prevent users from forgetting to pump up a fresh supply each time.

The instrument is chiefly valuable for use on trunk lines over long distances, as any leakage on the line can be compensated by using additional battery power, and very good results have been obtained with it on lines upward of one hundred miles in length and passing through six or eight exchanges, and therefore subject to a considerable amount of leakage. In general four Leclanche cells are sufficient.

Our account of this remarkable instrument would be incomplete without some description of the system of telephonic communication which Mr. Bell has devised specially for use with the water jet transmitter, its principal advantage being that it requires a battery only at the exchange, but not at the subscribers' instruments. With the transmitters now in use it is not practicable in the case of lines of any length to trans-

FIG. 3.

mit speech by the direct action of the vibration of the transmitter in varying the resistance of the line circuit, and therefore an induction apparatus is used, the transmitter being placed in the primary and the line in the secondary circuit, and this involves the use of a battery at each sub-station. In the arrangement shown in Fig. 4 a battery, B, of high e.m.f. and low resistance, is put to earth at G, and connected with a line, *d*, which divides into two branches, *a*, and a^1, containing the transmitters, D and E, and the receivers, D^1 and E^1. The receivers are put to earth at G^1 through the wires, S S. Disturbances in either transmitter will not be communicated to the receiver at the other station, because the earth connection through the battery forms a low resistance shunt. If, however, a suitable resistance, R_1, is inserted in the branch, *d*, as shown in Fig. 5, this will no longer be the case, and it is easy to make the resistance, R_1, so large that practically the whole disturbance originated at D is transmitted to E^1, more cells being added to the battery if necessary to make up for the additional resistance. The inventor has found experimentally that in the case of short lines (such as ordinary town lines) the resistance of R_1 may be varied from about 2,000 to 8,000 ohms

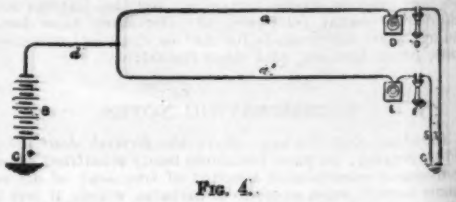


FIG. 4.

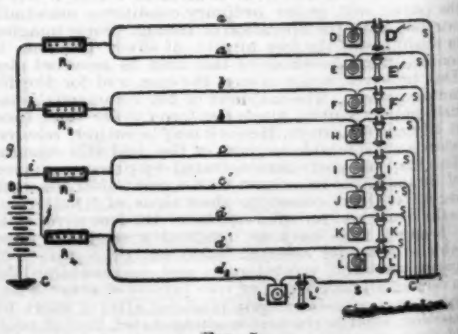


FIG. 5.

without appreciably affecting the action of the transmitter, supposing the jet transmitter to be used, the resistance of which is about 1,000 ohms.

In practice it is desirable to make the resistance of R_1 adjustable, as it may then be varied as may be requisite to compensate for variations in leakage along the line. If the stations, D and E, were connected directly through a battery at the central station, a battery of twice the e.m.f. would be required to give equally good results, as has been proved to be the case by experiment. Further, if the two stations are con-

nected directly through the central battery, and the transmitters are of unequal resistance, the speaker at the low resistance end will not be heard so well as the one at the high resistance end; but this is not found to be the case when the connections are made as in Fig. 5. A single battery can be used for all the subscribers to one exchange if desired. Thus, Fig. 5 shows two additional pairs of subscribers using the trasmitters, F and H and I and J, connected through the resistances, R_3 and R_4, and the wires, h and i, with the wire, *g*, from the battery, and it is found that each pair can carry on conversation without interfering with, or being overheard by, any of the others. Fig. 5 also shows a group of three transmitters connected through the lines, *d*, d^1 and d_2, the resistance, R_4, and the wire, *j*, with the central battery. In this case a speaker at one transmitter —K, for example—will be heard in the receivers, L^1 L^1, at both of the other two stations.

[NATURE.]

MAGNETIC STRAINS.

IT has long been known that when an iron rod is magnetized, its length is in general slightly increased. This phenomenon was first studied by Joule about the year 1847, and most of his experimental results have been confirmed by other physicists, among whom may be mentioned the names of Tyndall, Mayer, and Barrett.

Joule enunciated the law that the elongation of a magnetized rod is proportional to the square of its magnetization, a law which seems to have been pretty clearly supported by his experiments so far as they went. Now, when iron is subjected to the action of continually increasing magnetizing force, a point is at length reached when further increase of the force produces comparatively little effect upon the magnetization. The iron is then, in popular language, said to be "saturated," and is (or until lately was) commonly supposed to have attained a condition of magnetic constancy, so that none of the properties of the metal connected in any way with its magnetism would be materially affected by any increase of magnetizing force, however great, beyond what was necessary to produce saturation.

Joule carried many of his observations up to the so-called "saturation point," and then, perhaps naturally, seems to have assumed that nothing would be gained by going any further, and accordingly discontinued his experiments. It is, however, a somewhat remarkable fact that, although his interesting discovery was soon widely known, an account of it appearing in almost every text book dealing with electricity, while an exhibition of the phenomenon in question became a familiar lecture illustration, yet for the thirty-seven years following the publication of Joule's paper it seems never to have occurred to any experimenter to try what would be the effect of subjecting an iron rod to stronger magnetizing forces than those applied by Joule himself. Perhaps I may be pardoned if I refer to the accidental circumstance which led me to do so.

In 1884, a reprint of Joule's scientific papers was issued by the Physical Society, and I then read, for the first time, his original memoir on the effects of magnetism upon the dimensions of iron and steel bars. I had recently been engaged in an investigation of the heat-expansion of sulphur, changes in the length of rods of that substance being indicated by their action upon a small movable mirror which reflected the focused image of a wire upon a distant scale; and it struck me that a similar method would be well adapted for the exhibition of magnetic expansions. Wishing to have the satisfaction of witnessing some of these effects, I put together a rough apparatus, in which the mirror principle was applied. The battery employed consisted of five large bichromate cells, the zinc plates of which were immersed in the solution by the action of a treadle, and withdrawn by an opposing spring when the pressure on the treadle was removed. The circuit included the magnetizing coil, a galvanometer, and a contact key.

The first results of experiments made with this apparatus were disappointing. Everything appeared to be quite right: the mirror worked perfectly, as was shown by its deflection when the temperature of the iron rod was slightly varied; the iron was well annealed, and there could be no doubt that the magnetizing force used was more than sufficient to "saturate" it (in the popular sense). Yet the elongation indicated when the circuit was closed was only a small fraction of what had been expected, the movement of the focused index upon the scale being, indeed, scarcely perceptible.

The arrangement was varied in several details, and further attempts were made, but without any better success. In these perplexing circumstances I happened to remove my foot from the battery treadle while the contact key was still depressed, and at the moment of doing so I noticed a curious "waggle" of the focused image. A movement of the same kind was found upon trial to occur if the zincs were lowered into the liquid while the key was down. The operation was then performed very slowly, and the exact nature of the waggle became clearly revealed. As soon as the zinc plates touched the surface of the liquid, the index immediately jumped into a position indicating a certain small elongation of the magnetized rod. As the zincs went in deeper, this elongation at first steadily increased, but only up to a certain point, after which it was *diminished*; and when they were completely immersed in the liquid, the focused index had returned nearly to the zero position, showing that the elongation had almost entirely disappeared. When the zincs were again slowly raised, the same cycle of changes occurred in inverse order.

The conclusion obviously suggested by these observations was one that could not be readily accepted. It appeared as if the magnetizing force which had been used in the first instance was *too great* to produce Joule's effect, and that it was only when the current was diminished by increasing the resistance of the battery that the elongation of the iron became well developed. This view clearly involved the assumption that the common notions as to magnetic saturation must be at least in part erroneous, and I therefore endeavored to find some other explanation of the apparent anomaly. In particular, I suspected that it might be due to electro-magnetic action of the kind known as "solenoidal suction" between the iron rod and the coil; but a few careful experiments convinced me that, although this might well have been the case, yet in fact it was not so. Nor did any other hypothesis present itself which would bear examination, and I accordingly fell back upon the first and natural interpretation of the facts, which implies that magnetizing force may exert an important molecular influence upon iron even when its magnetism is saturated.

A fuller investigation of the phenomenon was then made with very delicate apparatus and greater battery power, and the results were communicated during the next year to the Royal Society, the principal conclusion arrived at, so far as regards iron, being the following: When an iron rod is subjected to a continually increasing magnetizing force, its length at first increases to a maximum and then diminishes, ultimately becoming actually *less* than when the rod is unmagnetized.

I have since published accounts of further experiments, and among others of a series in which iron rings surrounded by magnetizing coils were used instead of straight rods. The changes produced by magnetization in the diameter of the rings were of exactly the same nature, showing conclusively that the effects before observed could not have been due to any unexplained action of the ends of the rods.

By the kindness of Mr. W. H. Preece, F.R.S., who placed at my disposal the large secondary battery used in lighting his house at Wimbledon, I have recently been able to repeat some of my experiments with magnetic fields of exceedingly high intensity. Rods of iron, nickel, and cobalt were thus tested, and the results are clearly shown in the accompanying curves, where the

abscissæ represent the magnetic fields due to the coil in C. G. S. units, and the ordinates the elongations and retractions of the rods in ten-millionths of their lengths.

The retraction of iron, it will be seen, becomes ultimately greater in amount than its maximum elongation, and reaches a limit in a field of 1,000 or 1,100 units, after which its curve becomes sensibly parallel to the horizontal axis. Nickel, unlike iron, retracts* from the very commencement, rapidly at first and afterward more slowly, until in fields of 800 units and upward its length becomes apparently constant. Cobalt behaves in a very remarkable manner. While the field is comparatively weak, no sensible change in either direction can be detected. After about 50 units of magnetizing force, the rod begins to contract, attaining its minimum length with 300 or 400 units. But instead of remaining unchanged in fields stronger than this, it again becomes longer. At 750 it regains its original length, and thence up to 1,400, the highest field reached in the experiment, it continues to elongate steadily.

It should be understood that so far as mere details are concerned, the curves in the diagram relate only to particular specimens of the metals in question. With different rods there will be certain small variations, dependent upon the purity of the metals and their physical condition. But I have always found that under increasing magnetizing force iron is at first extended and then contracted, nickel is contracted from the beginning, while cobalt is first contracted and afterward extended.

My best thanks are due to Mr. Preece, not only for having given me the opportunity of carrying out the experiments described above, but also for the exceedingly kind and cordial manner in which he did so.—*Shelford Bidwell.*

THE INFLUENCE OF ALUMINUM UPON CAST IRON.†

By W. J. KEEP, C.E., Prof. C. F. MABERY, S.D., and L. D. VORCE.

ALUMINUM is a metal obtained from its oxide alumina. It is white in color and very tenacious, and it alloys readily with iron. Cast iron ordinarily used is iron which contains all the carbon that it could absorb during its reduction in the blast furnace. This carbon, when found in chemical union with the iron, is called combined carbon. In this state it cannot be seen. It is also found mechanically mixed with the iron in the form of graphitic carbon, when it becomes visible. Other elements commonly found in cast iron are phosphorus, sulphur, manganese, and silicon. The natural condition of carbon in iron is the combined state. The presence of silicon drives a portion of the carbon into the graphitic state.

Sulphur, manganese, and phosphorus do not cause the carbon to leave its natural combined state, and if silicon be present, these elements either drive it out or overpower it. Carbon is therefore a passive element, and is made to change its form by the presence of other elements. It is this change of carbon which indicates to the eye the influence of any element upon the cast iron. Iron and combined carbon or carbureted iron is called white iron, and the grain is generally very fine, and often even, and the metal is very hard. Graphite darkens the fracture until it becomes a very dark gray, and the grain is coarse and irregular. With increase of graphite the metal becomes soft. We shall confine ourselves in this paper to the influence of aluminum upon cast iron.

Let us for a moment review the present knowledge on this subject. It is known that fused wrought iron, a mixture of cast iron and steel, or steel alone, either of which would make castings which would be full of blow holes, will make solid and homogeneous castings if as small a quantity of aluminum as one-tenth of one per cent. is added just before pouring. Also that such addition causes the iron to remain fluid long enough to allow its being cast into moulds. It seems to be the general opinion that the aluminum does not remain in the metal, but that it exerts its influence between the time of its introduction and the time of its departure. This seems to be the sum total of the present information regarding the influence of aluminum upon iron.

We propose in this paper to give the results of a series of very carefully conducted tests, to further substantiate the statements just made, and to settle the question as to whether aluminum remains in the casting. Also to determine the influence of this metal upon the physical structure and upon the composition of iron. The physical tests that we have employed are what are known as "Keep's tests;" and by them we are enabled to make apparent to the eye the influence of any element upon cast iron.

When it was understood that we were to undertake this examination, the Cowles Electric Smelting and Aluminum Company kindly furnished us with what ferro-aluminum we needed, and Prof. C. F. Mabery and L. D. Vorce volunteered to undertake the chemical examination of the test bars. The results of these investigations will be appreciated when it is understood that we began without the least expectation of the very important results we have obtained, and that the methods for the determination of minute quantities of aluminum were so imperfect that the small quantities used in the "Mitis" process could not be determined, if they still remained in the castings.

Regarding the physical tests, we should state that we use two bases, one a white iron, with composition Si 3·86, Al 11·42, P ·263, S ·0307, Mn ·092. The other, a gray Swedish iron marked FLM, with composition Si 1·249, P ·084, S ·04, Mn ·187. The ferro-aluminum contained silicon.

The melting was done in a covered plumbago crucible, in a coke furnace, driven by a blast of two and a quarter ounces. The test bars were one foot long and cast in pairs, one being half an inch square and its mate one-tenth of an inch thick and one inch wide.

We started with thirty pounds of the base in the crucible. At the first heat there were cast four pairs of bars from the base alone, which took five pounds of metal. After allowing the remaining metal to become solid we returned the runners of the first cast, and added four pounds of the base, and returned the crucible to the furnace. When nearly melted we added enough ferro-aluminum to bring the percentage of aluminum in the whole to where we wished it, for the second set of bars. We proceeded in like manner through the entire series of heats. To arrive at the influence of the aluminum, we made another series of heats, with the same base, with exactly the same conditions, only we did not add the aluminum.

The difference between the two series of tests gives the effect of the aluminum.

We shall consider this subject under the following heads: 1st. The solidity of castings and the prevention of blow holes. 2d. Does the aluminum remain in the iron to exert an influence when the iron is remelted? 3d. The effect of the aluminum upon the grain, or the changing of the carbon from the combined to the graphitic state. 4th. The taking away the tendency to chill. 5th. The prevention of sand scale. 6th. The effect upon hardness. 7th. The resistance to a load suddenly applied, or a dead weight. 8th. The resistance to a load suddenly applied, impact. 9th. The elasticity. 10th. Permanent set. 11th. The effect on the shrinkage of the iron. 12th. The fluidity of the melted metal.

FIRST—THE SOLIDITY OF CASTINGS AND THE PREVENTION OF BLOW HOLES.

All of our tests bear upon this subject, but we have made one test, using the white base iron and one-tenth of one per cent. of aluminum. It is almost impossible to get a solid casting of the white base alone, and its resistance to weight is generally about 175 pounds for the ½ inch square bars, and its resistance to impact is about 100 pounds. We have obtained, however, exceptionally sound castings of this base, and we shall use the strength of such castings for comparison.

These sound castings of the white base alone resisted a weight of 379 pounds. With one-tenth of one per cent. of aluminum added, it resisted 545 pounds, a gain of 166 pounds, or about 44 per cent. from this small addition. Measuring the resistance to impact, the white alone was 289 pounds, with aluminum 254 pounds, or about 6 per cent. gain. The castings appear of slightly finer grain, and the character of the crystallization is somewhat different, but the secret of the strength lies in the closing of space between the grains, or, in other words, in the increased solidity of the casting. No other change is noticeable in the metal.

A graphic representation of this test is not needed.

SECOND—DOES THE ALUMINUM REMAIN IN THE IRON TO EXERT AN INFLUENCE WHEN THE IRON IS REMELTED?

To determine this we made a series of six heats from the white base, and added to the first heat one-fourth of one per cent. of aluminum. This amount alters the grain very perceptibly, making it whiter and finer, and removing the tendency of the base to a slight specular appearance and giving a homogeneous fracture. It increases the strength above the base about 20 per cent. to resist weight, and for impact an increase of over 70 per cent. The next heat was a remelt of the first, with the runners of the first cast put back, and enough white base added to reduce the aluminum to two-tenths of one per cent. when the second cast was made.

Our comparison will now be made between this series and the comparison series of the base alone. Looking at the chart, we see that the effect of the aluminum in the second heat is greater than it was in the first case to which heat the aluminum was added. This is due to the increasing porosity at each heat of the base when melted alone, and to the solidity of the series with aluminum. At the third and subsequent heats the same result is apparent, the remaining aluminum causing more solid castings, though the continued additions of white iron at each heat, and the consequent lessening

* The retraction of nickel under magnetization was first observed by Prof. Barrett (*Nature*, XXVI., 565).

† From advance proofs of a paper read by W. J. Keep, Detroit, Mich., at the American Association for the Advancement of Science, August, 1888.—*Engineering and Mining Journal.*

of aluminum, render the castings less strong at each remelting. Yet the effect of the aluminum is so constantly apparent at each melt as to leave no doubt as to the presence even in the sixth remelting. The chart which we have prepared shows those effects, both as to weight and impact.

As we proceed with the description of other tests, it will be noticed that we add but a small quantity of aluminum at each heat, and depend upon the additions made at previous heats to bring up the required percentage.

The results of the tests show conclusively that the aluminum remains and exerts its influence in subsequent casts as fully as would be expected.

THIRD—THE EFFECT OF THE ALUMINUM UPON THE GRAIN, OR THE CHANGING OF CARBON FROM THE COMBINED TO THE GRAPHITIC STATE.

Let us say a few words in regard to the way in which, and the reason why, carbon takes on the graphitic form. All of the carbon, both combined and graphitic, which the iron is capable of holding when solid must be dissolved and exist as combined carbon in the melted iron. Cast iron made in the usual way contains all of the carbon that it can hold Very often cast iron when melted contains more carbon than it can hold in combination when at a lower temperature; if so, as the iron cools down, such excess of carbon will separate as graphite and rise to the surface. In any case, when a melted iron contains more carbon than the iron can hold in combination when cold, all of the excess will not be able to reach the surface, though it may not be visible in the casting to the eye. The introduction of other elements into the melted metal may alter its ability to hold the carbon. Sulphur causes it to let some go, while manganese enables it to hold more carbon in solution. Silicon also somewhat diminishes the capacity of the molten metal to retain carbon while it is liquid.

Aluminum allows most of the carbon to retain its natural combined form until the metal is too thick for the separated carbon to escape, but at the instant of solidifying aluminum causes the iron to drop a portion of its carbon from the combined state. This liberated carbon takes the graphitic form, and is imprisoned in the otherwise solid iron. The advantage arising from a change of carbon from the combined to the graphitic state at the instant of crystallization is that all the carbon thus liberated is imprisoned uniformly throughout the casting, and is not accumulated in pockets forming soft and hollow spots, as would be the case if liberated while the casting was yet fluid. Aluminum, more than any other known element, accomplished this. It not only changed white iron to gray, but seemed at once to change the whole character of the metal. The drop of carbon seems to be instantaneous, at the instant of crystallization, and for this reason the time taken in cooling has little effect. In fact, when the aluminum obtains full control of the carbon it would seem that the more sudden the cooling the more the formation of the graphite, and the thin portions of the casting are therefore as gray as the thicker portions. The powerful and positive influence of aluminum upon the carbon, and therefore upon the grain and color of the iron, is shown by an examination of the samples. Take those made from the white iron base, with almost no silicon present. The base alone gives a white bar full of blow holes. An addition of one quarter of one per cent. aluminum gives us not only a perfectly homogeneous and solid casting, but the color is darker, and the grain shows that some of the carbon has taken the graphitic form. The thin casting shows this even more than the heavier bar, showing that the change occurred suddenly, and that time had but little effect. Examining each bar in turn we see that each similar addition of aluminum produces a corresponding effect, until at the third addition, or three-fourths of one per cent., the casting is gray, with no sign of white, either in the square or in the thin bar.

The set of tests with the gray iron base, containing 1¼ per cent of silicon, shows that silicon and aluminum work together in the same direction, and that a slight addition of aluminum takes the white out of the casting at once, giving the same grain in a thin as in a thick casting.

This effect increases as the aluminum increases, and the indications are that at least up to four per cent., the limit of our experiments, the more aluminum, the softer and grayer the castings.

FOURTH—THE TAKING AWAY THE TENDENCY TO CHILL. (FIG. 1.)

If cast iron be cooled very suddenly, the carbon which the melted metal holds in combination will not have time to separate, and will be retained in the combined state. Such castings are called chilled castings. Chill is caused by molten iron running against a body which rapidly withdraws its heat, causing it to retain its carbon in the combined form. Back from the chill, where this instantaneous cooling could not exert its full effect, a portion of the carbon takes the graphitic

FIG. 1.

form. This property is made use of when it is desirable to obtain hard wearing surfaces, and in the same casting tough and soft central portions, as in car wheels. While this chilling effect is exceedingly valuable for many purposes, yet, generally speaking, the founder desires exactly the reverse.

We have said that aluminum causes the carbon to assume the graphitic form on the instant of solidifying, and, therefore, the sudden abstraction of heat does not imprison the combined carbon and cause chill.

This effect of aluminum is to give a uniform grain for thick and thin castings, and not allow the coldness of the mould to affect the grain.

FIFTH—THE THICKNESS OF SAND SCALE.

This is an important consideration, for the sand must be cleaned from the casting, and the surface must first be cut before the interior can be reached. To prevent the iron from burning the sand into itself, and thus forming a scale, a plumbago facing is sifted on the surface of the mould, but it is difficult for the facing to lie on the surfaces, or to resist the intense heat of the metal. When aluminum in an iron causes the dropping of the graphite from the mass of the metal, that graphite which is on the surface of the casting separates and forms a perfect plumbago facing, which opposes the sand and the heat. It will therefore be seen that in castings having sufficient aluminum to cause this separation of graphite, there will be sand clinging to the face, and that the surface will be soft as the interior of the casting. Every iron worker will appreciate this good effect of aluminum.

SIXTH—THE EFFECT UPON HARDNESS.

Hardness in cast iron is caused by the carbureted or white iron in masses large enough to oppose the tool. If the carbureted iron exists in minute threads stretched around atoms of graphite, a tool will easily cut it, and it will not be considered hard. This graphitic carbon, minutely dividing the mass, gives the tools of the workman a chance to cut or break the films of metal, giving what we call softness to the iron. The later the carbon is dropped, the smaller will be the atoms of graphite and the closer the grain. Yet this greater subdivision will, for the reason just given, make the iron work more easily. The fineness of the grain of iron affected by aluminum causes such iron to be much more easily cut than iron of coarser grain.

The power of wrought iron and steel to resist extension is so great that where such stresses are to be resisted, decarbonized metal should be used. The resistance of any cast iron to crushing is so great that we need not consider this. The forces which cast iron structures should be made to resist, aside from crushing, are a dead weight, or a blow applied transversely. We should therefore test cast iron with these forces.

SEVENTH—RESISTANCE TO A LOAD GRADUALLY APPLIED, OR A DEAD WEIGHT. (FIG. 2.)

If we compare the transverse breaking weights of the two series which we have been considering, number by number, we perceive that the aluminum has increased

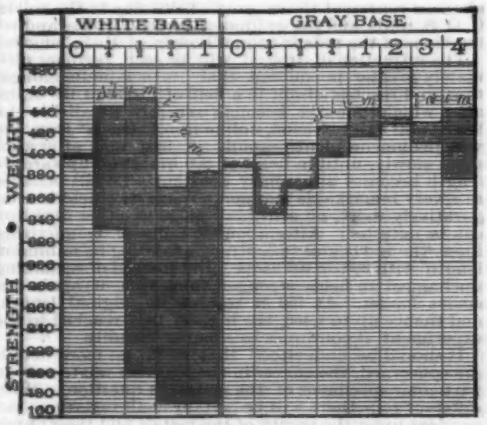


FIG. 2.

the strength to sustain a constant load. This is a very important effect, and, perhaps, comes partially from the tenacity and strength of aluminum itself, but probably more from the uniform grain of the iron.

EIGHTH—RESISTANCE TO A LOAD SUDDENLY APPLIED, OR IMPACT. (FIG. 3.)

It may be thought that the effect is substantially the same, whether the force be a constant weight or suddenly applied blows. We shall at a future time prove

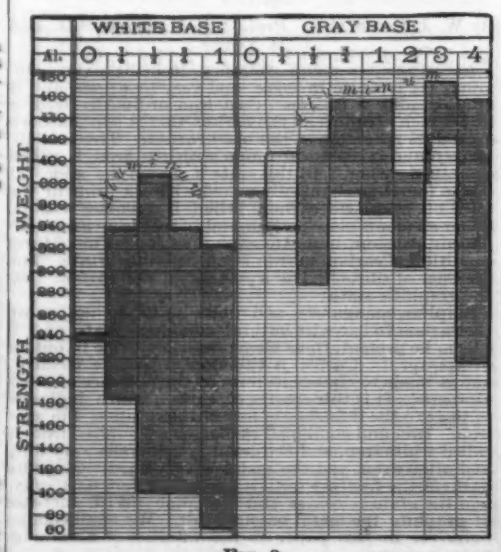


FIG. 3.

that the effects are not the same, and that an iron should be tested by a blow if it is expected to resist impact. By a comparison of the graphic representation, we see that the capacity to resist impact is increased by the addition of aluminum much more than the capacity to resist a dead weight. It will be seen at a glance that the test bars made with the white base are benefited far more than those made with the gray base. The reason for this is that the white base alone made porous castings; at each remelt this porosity increased, due to the continuation of the heat, running the strength down to 68 pounds at the fifth heat. The first and each subsequent addition of aluminum caused the castings to be perfectly sound, and the infinitesimal atoms of graphite deposited throughout the metal removed the rigidity and brittleness of the initial metal.

The gray iron base contained enough silicon to accomplish all this, and the only effect on strength that the action of the aluminum on carbon could have would be to increase the fineness of the grain, unless the toughness of the aluminum itself could give strength to the casting, though the aluminum no doubt removed any slight blow holes that existed in the initial gray metal. This leads us to notice that each addition of aluminum increases the strength over that of the initial metal. We must expect that after we have added enough aluminum to cause a solid casting and to remove the brittleness which the dividing up of the mass by the atoms of graphite accomplishes, any further additions of aluminum and consequent increase of graphite (which has no strength of itself) must weaken the casting.

NINTH—ELASTICITY. (FIG. 4.)

The compactness and closeness of the grain of cast iron, when aluminum was the agent by which the graphite was precipitated, and the fine attenuation of

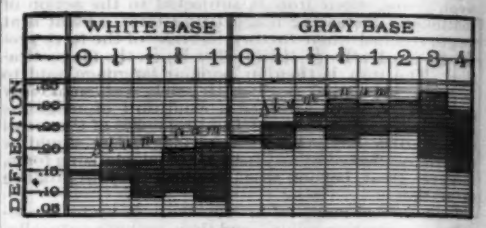


FIG. 4.

the veins of iron and combined carbon, cause the metal to be very elastic, and, as we have seen, not so brittle as without aluminum.

TENTH—PERMANENT SET.

This is caused by the compression of the graphite within the framework of iron and combined carbon. When this compression of graphitic carbon is produced by transverse bending, the framework of the metal also takes on a permanent form, which cannot be altered, except by a greater force than was before applied. The fineness and compactness of iron alloyed with aluminum gives less permanent set than iron equally as soft when such softness is produced by silicon.

ELEVENTH—THE EFFECT ON THE SHRINKAGE OF THE IRON.

The more suddenly and completely the carbon is changed from combined to graphitic at the instant of crystallization, the more space will the casting occupy. When the casting is cold it will, therefore, have contracted less than if more carbon had remained combined. White iron, having most of its carbon in the combined state, shrinks from one-fourth to one-third of an inch in each foot. Gray iron sometimes shrinks as little as one-tenth of an inch to each linear foot. As the combined is the natural state for the carbon, we may say that this maximum shrinkage is the natural shrinkage for cast iron having its carbon combined. We can, therefore, say that aluminum takes out or reduces shrinkage. This is a very great advantage, as shrinkage, when a sufficient quantity is added, requires great skill in the preparation of patterns to prevent warping and cracking and violent internal strains within the castings. The lessening of shrinkage avoids these evils, and is therefore a great gain.

Looking at Fig. 5 for shrinkage, we see the most conclusive proof of our explanation of the way in which

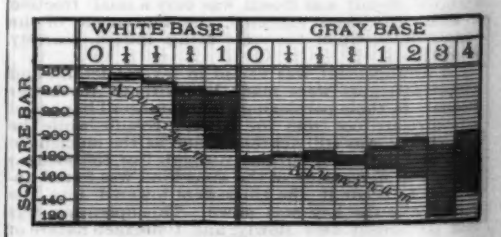


FIG. 5.

shrinkage is lessened. With both the white and the gray bases, during the first two additions the shrinkage of the square bar is slightly increased. The influence of the aluminum thus far has been in the direction of elimination of blow holes and causing an even distribution of the dark and light grains. At the third addition, however, when the amount reached three-fourths of one per cent., the effect was appreciably felt upon the carbon, as seen by the color, and as we should expect, from the deposition of this large bulk of graphite, the casting does not shrink as much, and, each addition of aluminum increasing, this bulk of graphite decreases the shrinkage.

The effect upon the grain and color of the thin bars of the series (Fig. 6) is very remarkable, showing that the aluminum has changed enough carbon to graphite to produce a dark, even-grained casting. The effect upon the shrinkage of thin bars is as we should expect, and is more marked even than in the square bars. The shrinkage in thin bars of the white series shows a constant decrease as the aluminum increases, but in the series for comparison, the shrinkage dropped still

more rapidly. If a new crucible were used in commencing this comparison series, enough silicon might have been absorbed to produce this effect. This leads us to remark that on account of the variations of conditions in any series of tests, that cannot be foreseen,

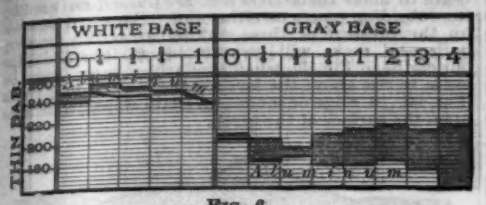


FIG. 6.

we must avoid drawing any but general conclusions, and these should be based upon a large number of experiments.

TWELFTH—THE FLUIDITY OF THE MELTED METAL. (FIG. 7.)

Our tests of fluidity are correct as far as each individual heat is concerned, but variation may be due to the heat of the metal of that particular cast when poured. Viewed in a general way, the indications are that with the white base, with almost no silicon, the aluminum has increased the fluidity; judging from the series with the gray base, we would say that combined with silicon, aluminum reduced the fluidity, but later tests show that the aluminum, to a very marked degree, increases the fluidity.

Our remarks in connection with shrinkage show that a sharp casting is produced by the instantaneous dropping of graphite when crystallization takes place, and that if the iron is fluid enough to fill the mould any extra fluidity causes the iron in shrinking to draw away

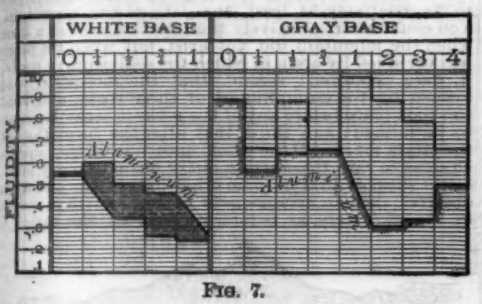


FIG. 7.

from the mould. Again, the percentage of aluminum necessary to bring about these desirable results will be too small to have much effect upon the fluidity of the metal.

The fact of the iron giving sharper and more perfect castings, caused by the deposition of graphite at the instant of solidification, might cause the iron to be pronounced more fluid, if judged by the appearance of the castings. No doubt the presence of varying quantities of manganese, sulphur, phosphorus, and silicon in the cast iron used would modify the influence of aluminum, and until this is understood it may require considerable experiment to determine the amount of aluminum required or how it shall be introduced.

This hurried presentation of the remarkable effects of aluminum upon cast iron will give an idea of the great benefit which is now promised to the iron founder by the rapidly falling price of aluminum as cheapened by the electric furnace.

SUPERFICIAL TENSION.

LET us take a glass of water; is the liquid that it contains constituted the same everywhere? It was for a long time believed to be, but it is not so any longer. To get some idea of the matter, let us examine the forces that attract the particles. In the first place, I say that there are attractive forces, for if I plunge a pencil in water and then remove it, there will be a drop suspended from it. If we imagine that a horizontal plane intersects the drop, all the particles situated beneath such plane must be regarded as sustained by those that are above, without which there would be no equilibrium. This cohesion is evidently due to attractive forces.

On another hand, I say that there are repulsive forces, which tend to separate particles. In fact, if I leave the glass of water to itself, the liquid will finally all evaporate. Is not this a proof that if there are forces that have the effect of bringing the particles of liquids together, there are others by virtue of which the particles separate?

It is by studying the constitution of liquids from this point of view that I have reached the following conclusion, viz., that an equilibrium cannot occur in the midst of a liquid, between the attractive and repulsive forces, without there being in the immediate vicinity of the free surface a tendency to a separating of the particles, and with this tendency the attractive forces are at continuous war. But what is the thickness of the stratum which is the seat of said tendency? Plateau and Quinke, by different processes, found that the thickness of the superficial stratum in which the tension exists does not exceed $\frac{1}{10000}$ of a millimeter. What is the intensity of the contractile force? It varies from one liquid to another, and in the same liquid; it diminishes in general when the temperature increases. At 15° C. the tension of distilled water is about 7·5 milligrammes per millimeter of length; the tension of olive oil is 3·6; of petroleum, 2·6; of absolute alcohol, 2·5; and of ether, 1·88 milligrammes.

But it is time to demonstrate the existence of contractile force by a few very simple experiments.

First Experiment.—Let us take two pencils, one of which, of light wood, is no thicker than 3 or 4 millimeters. Let us place them against each other, so that contact shall occur in a straight horizontal line, and let us place in the space contiguous to this line several drops of common but pure water, so that the portions in the vicinity of the line of contact shall all be wet. There will then form a small liquid mass adherent to the two pencils, of concave curvature, and the section of which is shown at *a b* in Fig. 1. After this, the pencil of light wood will remain suspended

FIG. 1.—PENCILS HELD BY SURFACE TENSION.

from the other, owing to the tension of the concave surfaces, *a b*, that extend from the two sides of the line of contact. For example, if the length of the pencils is 12 centimeters, the weight that can be sustained is $2 \times 120 \times 7{\cdot}5 = 1{,}800$ milligrammes. The pencil must, therefore, weigh less than 1·8 gramme.

Second Experiment.—Let us take a perfectly cleaned ring of copper wire about 8 centimeters in diameter and lay it carefully upon the surface of pure water contained in a previously well washed capsule. The ring will float, and that, too, despite its being 8·8 times denser than water. It is because all the tensions of the liquid that exist about the ring give rise to a resultant directed upward (Fig. 2). A very simple cal-

FIG. 2.—COPPER RING FLOATING ON WATER.

culation shows that the weight of the ring amounts to nearly $\pi \times (\frac{1}{20}) \times \pi \times 80 \times 8{\cdot}8$ milligrammes = 1·75 gramme. On another hand, the maximum effect of the tensions is $2 \times \pi \times 80 \times 8{\cdot}5$ mmgr. = 3·77 grammes. It will be seen, then, that, leaving aside the thrust of the liquid, the effect of the tension is greater than double the weight of the ring.

In the same way we can float needles, globules of mercury, thin platinum rings, etc., on the surface of water.

Third Experiment.—Let us procure a sheet of light, unglazed paper, say about 17 × 3 cm., and let us bend the edges so as to form an oblong box (Fig. 3). This done,

FIG. 3.—ACTION OF WATER ON PAPER BOX.

let us place the box on a table, and, having wet the inner surface with a brush, let us pour water into it up to a height of 4 or 5 mm. The tension of the liquid surface will at once draw together the long sides of the box till they touch.

Fourth Experiment.—Let us take a cylindrical cork (Fig. 4), say 2 cm. in thickness and 4 in length. In the center of one of the ends let us insert a very fine wire,

FIG. 4.—EFFECT OF TENSION UPON A WIRE RING.

6 or 8 cm. in length, provided with a hook or other device to receive a weight. To the other end of the cork let us affix an iron wire ring, 10 cm. in diameter, through the intermedium of two pieces of the same wire, *a b*, which are so inserted in the cork that the plane of the ring is at right angles with the axis of the cork, and placed concentrically with respect to it. This done, let us plunge the apparatus in water contained in a vessel of sufficient depth. If the weighting has been properly done, the cork will stand upright and will emerge but 8 or 10 mm. above the level (Fig. 4). If, afterward, the entire affair be made to descend in the liquid and be left to itself, the ring will no longer leave the water, but will rise slightly above the surface and produce a double concave meniscus. Here the effect of the superficial tension gives rise to a resultant directed downward, and sufficient to counterbalance the increase of the thrust.

If the ballast is proper, this resultant increased by the weight of the system very slightly exceeds the upward thrust of the liquid. It then suffices to bring near to the liquid a little wadding saturated with ether (which diminishes the superficial tension) to see the ring rise from the water, apparently spontaneously, and resume its first position of equilibrium.

Up to the present, we have operated only upon relatively large liquid masses, and having only one free surface; let us now cite new proofs of tension furnished on the contrary by small masses presenting two superficial strata in contact with the air and capable of producing effects twice more marked.

Fifth Experiment.—Let us take a mixture of 25 grammes of castile soap, 25 of rock candy, and a liter of water, and into this plunge a frame of iron wire and then take it out. We shall see the space occupied by a plane film (Fig. 5) which seems to have no weight, so

FIG. 5.—EXPERIMENT WITH FILMS.

little does it appear to be inflected. In measure as it becomes thin, the contractile force of the two faces gets the better of it further and further, and finally resigns absolute mistress over it. Let us place upon the film a cotton or silk thread tied together at the ends. This will assume any form whatever, because there will be a liquid film internally as well as externally. But the instant that the inner film is ruptured, the thread abruptly stretches out and becomes perfectly circular. This is the effect of the combined tensions of the two faces of the remaining film. The thread takes the form for which the surface that it limits is as great as the length of the thread permits. Now, on analysis it is demonstrated that such form is that of the circumference of a circle. . . .

The preceding experiments have been made with a single liquid: but it will be seen that if we operate with two liquids of different tensions, centrifugal or centripetal motions will be produced, according to the extent of such tensions.

If two liquids, such as alcohol and water, mix, the surface of contact has no tension, and here is why: If, upon water, we place a drop of alcohol (2·5) or ether (1·88), we perceive a violent motion of extension because

the tension of water (7·5) notably exceeds that of alcohol or ether. Immediately after the spreading out there is a retreat of the liquid toward the point where the deposit was made. It is because the evaporation of the alcohol or ether has cooled the subjacent liquid, which thus acquires a stronger tension than that of the more distant portions.

In cases where the liquids put in contact do not mix (as water and oil), the surface common to these liquids has a tension that must not be neglected.

When we place a drop of spirit of turpentine (2·9) or oil of lavender (3) upon pure water contained in a wide capsule (a common plate will answer very well), we at once remark a very rapid extension of the drop, which becomes converted into a very thin film that sometimes exhibits the most beautiful colors. This is due to the fact that the tension, 7·5, of pure water prevails over the sum of the tensions of the oil employed and of the surface common to the two liquids.

As the rapid extension occurs only with a diminution of the temperature of the liquid of the primitive drop, the film does not preserve its form, but subdivides into a multitude of disconnected portions, sometimes figuring small polygons and recalling the aspect of fine lace. It is what Mr. Tomlinson calls a cohesion figure. With oil of lavender, the figure soon resolves itself into a multitude of scarcely visible lenticulæ.

The placing of one or two drops of oil upon water generally suffices to render the extension of a new drop impossible. This is because the tension of the superficial layer has become equal to or less than the sum of the tensions of the oil and of the surface common to the two liquids.

I have, since 1869, most carefully studied these phenomena, the explanation of which had, unknown to me, been given some time before by Mr. Marangoni of Florence.

If, on the surface of pure water, we place a solid body which is more or less soluble therein, the equilibrium of the superficial stratum of water will be broken. If the solution occurs unequally around the particle, the latter will exhibit abrupt rotary and sidewise motions. For example, let us place upon the surface of distilled water a thread united at the two ends, and let us do this in such a way that the thread touches the liquid through all its lower parts without being submerged anywhere. Now let us drop within the interior a few fragments of camphor. The particles will at once rapidly revolve and change place, and the thread will assume the form of a perfect circle. What is curious is that the flexible contour allows itself at times to be crossed by the inner liquid at one or more points, and that then all the circular film moves on the surface of the liquid. It must be understood that all these phenomena are due to the unequal distribution of the camphorated water, the tension of which is but 4·5 mg.

Apropos of the extension of oil upon water, let me be permitted to allude here to an important application that I made known in 1882. Let us recall the fact that, per millimeter of length, the surface of water experiences a tension of 7·5 milligrammes. Now imagine a surface of water one millimeter square, and let us inquire what power must be expended in order to increase such surface so as to double it. We shall have to conquer a series of small forces whose sum amounts to 7·5 milligrammes, and to describe at all the points of application of these elementary forces a length of one millimeter. Now, as the work is exactly equivalent to the product of the intensity of the force by the space traversed on the straight line where the force is, we shall have to effect here a work of 7·5 milligrammes-millimeters. Then this work expended will be found again, as disposable energy, in the new square millimeter of free surface. It is this energy of 7·5 milligrammes-millimeters that I have called the potential energy of pure water. Let us not forget that this energy resides in a stratum that is not over $\frac{1}{7692}$ of a millimeter in thickness. We shall then understand that in the superficial stratum of the ocean there is stored up a mechanical power of which nothing can give an exact idea.

Let us now suppose that of two superficial strata one slides over the other by the effect of the wind, for example. The completely covered stratum will have lost its free surface, and, with it, its characteristic potential energy. If the sliding proceeds slowly, the energy will be replaced by an equivalent quantity of heat; but if the phenomenon proceeds rapidly, the potential energy lost gives rise to an increase of speed. If, then, the wind communicates to certain strata of the sea a greater velocity than to the neighboring ones, these latter will be covered by the first, which will proceed to cover others more distant, and so on. This is why every wave in the process of formation is composed of portions whose velocities are greater toward the top. When the wind is violent, the increase of speed produces upon each wave a crest that becomes more and more prominent, and which finally becomes disintegrated in space, or, as it is said, breaks into foam.

It follows from this that every cause capable of preventing the sliding of the superficial strata of the waters of the sea over the others will form an obstacle to the gradual increase of the live force of the liquid masses. Now, exactly such a cause is found in oil which covers the surface of the sea to a sufficient extent. By virtue of its specific lightness, the oil always rises to the surface and renders the sliding of one stratum upon another impossible. This explains the efficacy, so mysterious at first sight, of oils that are capable of being spread out in films of incredible tenuity, say from $\frac{1}{12820}$ to $\frac{1}{25640}$ of a millimeter. As soon as the sliding of the strata is interfered with, it is clear that the formation of crests or breakers will become impossible likewise.

But this is not all. Not only does oil prevent the sea from breaking into foam, but it is also capable of converting crested waves into regular undulations, forming swells. In fact, if a high wave is approaching a portion of the sea covered with oil, the latter suddenly spreads over the concave surface and soon reaches the crest. From this moment, the sliding of the superficial strata around the volute that surmounts the wave becomes impossible. Hence, a resistance which accumulates the liquid at the top of the crest, and the fall of the latter with great noise upon the sea. This is how breakers are converted into swells, as has already been advanced by Aristotle, Pliny, and Plutarch.

The theory that I advanced in 1883 was confirmed last year by Vice-Admiral Cloue, who, taking as a basis the favorable conclusions drawn from 203 reports of captains of ships, did not fear to assert that the question of the use of oil for calming breakers at sea appeared to be solved. To-day, improvement in such use is under constant study in England, Scotland, the United States, Australia, and France. Why is it not so in Belgium? Doubtless on account of the narrow prejudice that leads people to say: "What can a liter of oil do against mountains of sea water?" Fortunately, as I stated a month ago to the Academy, I can answer with assurance that a very thin film of oil transforms and calms the movements of billows; it is a strange fact, if you please, but it is an absolutely indisputable one, and one which, moreover, proceeds from my theory of the variation of energy of liquid surfaces. This is why I finish by once more making the wish that no ship, no fishing smack, no lifeboat, may ever more leave a Belgian port or coast without having a sufficient supply of oil, along with the necessary apparatus for using it.—*M. Van der Mensbrugghe, in La Nature.*

[Continued from SUPPLEMENT, No. 661, page 10563.]

GEOLOGY.

By ARCHIBALD GEIKIE, LL.D., F.R.S.

IV. The Origin of Mountains.

IT is common to speak of the "eternal hills" as if they had existed from the very beginning of the world's history. And certainly few objects upon the surface of the globe convey to the mind such an impression of vast antiquity. As far back as history or tradition can go, the mountains have remained without sensible change; and thus, because they have always appeared to man to be what they still are, he is apt to think of them as parts of the original architecture of the planet.

And yet from what has been learned in some of the foregoing lessons, you will be prepared to find that, old as the mountains undoubtedly are, they do not belong to the beginning of things. It is still possible to trace out their origin, and to get back to the records of earlier times before they existed at all. If I ask how this knowledge can be gained, you will doubtless answer that it can only be by examining the rocks of which the mountains consist. You have already learned how rocks tell their story. It is only a further stage of the same kind of reasoning to inquire what the rocks tell regarding the birth of the mountains.

First of all, then, when any chain of mountains is examined, it is found to be made of rocks belonging to one or more of the three great classes—with which you are already acquainted. In particular, the great mass of most mountain chains consists of various kinds of stratified rocks—such as sandstones, conglomerates, limestones, and others. Now you have found that these rocks have been laid down under water, most of them under the sea. They often contain the remains of shells, corals, sea urchins, or other marine creatures, and these remains may be taken out of the rocks even at the summits of the mountains. No clearer proof than this could be required to show that mountains are not so old as "the beginning of things," for these fossils prove that where the mountains now stand, wide seas once rolled.

Again, mountains, which consist of rocks formed originally under the sea, must owe their existence to some force which could raise up the bed of the sea into high land. That force has been already alluded to. As a consequence of the slow cooling of our planet, its outer crust, under the enormous strain of contraction, has been forced up into ridges in different places, with wide, sunk spaces between. The ridges form mountain chains, while the sunk spaces are filled with the waters of the ocean. If you look at a map of the world, you may trace out the principal lines of elevation, as they are called, over the globe. Perhaps the most remarkable of all the folds or puckerings into which the surface of the earth has been ridged up is the long line of mountains which runs down the whole of the continent of America. You observe that the various ridges of the Rocky Mountains, of Central America, and of the Cordilleras and Andes, are prolonged in one vast line of elevation. Other minor foldings are seen on the same continent, as, for instance, the chain of the Alleghanies, in the eastern part of the United States. In Europe we have a line of elevation stretching across the continent, and throwing off spurs in its course. It is seen in the Pyrenees, then in the Alps, whence after sending southward the ridges of the Apennines, it is carried eastward by the chain of the Carpathians, and then by the Caucasus to the Caspian Sea. The same line, however, reappears on the other side of that inland sea, and crosses the vast continent of Asia in two divergent lines; one of which turns southeastward, to form the grand Himalayas, while the other trends eastward across the great Asiatic table land to the shores of the Pacific Ocean. When you reflect upon these enormous mountain chains as the results of the cooling and contraction of the mass of the globe, you begin to feel how enormous must be the force which could crumple up solid rock into ridges many thousands of miles long and thousands of feet high.

But as the globe has been cooling and contracting since the very first, we may reasonably expect to find

FIG. 43.—Section of a series of Sedimentary Rocks originally deposited horizontally on the sea bottom.

that mountains have been uplifted at various times, and, therefore, that they differ from each other in age. A little attention to the rocks is enough to show not only that mountains are not all of the same age, but that even the same mountain has not been formed entirely at one time, but that one part has been raised up long before another.

Suppose, for example, that a series of ordinary sedimentary rocks, such as the sandstones, conglomerates, and shales, described in earlier lessons, has been laid down upon the sea bottom. These rocks would be formed one above another in flat beds (Fig. 43), until they had accumulated into a mass perhaps many thousands of feet in thickness. They might remain undisturbed for a long time. Let us further suppose, however, that they happen to lie in one of those weaker parts of the crust which, when the accumulated effects of the long-continued contraction of the earth's mass begin to make themselves felt, are pushed outward by the subsiding spaces on either side. Squeezed together by the pressure of these sinking areas, the formerly horizontal rocks will be crumpled up into folds (like our cloths in Fig. 40, when similarly squeezed), and be made to rise above the level of the surrounding tracts (Fig. 44). A ridge or mountain chain would thus arise upon the surface of the earth.

FIG. 44.—Section of a mountain formed of crumpled rocks, A, which have been contorted before the deposition of the flat rocks, B.

Such a ridge or chain formed out of sedimentary rocks (A), once horizontal but now contorted, could not rise up into the atmosphere without becoming a prey to those various forces which, as you have learned, are ceaselessly at work in wearing down the surface of the globe. The air, rain, springs, rivers, frosts, or the waves of the sea, would attack the newly formed mountain, and begin to waste its surface as soon as it raised its head above the level of the ocean. Deep furrows would in time be carved out of its sides, and all its decayed fragments would be washed down to the lower grounds. There these fragments would form new deposits, which would be laid down upon the edges of the older rocks, as in Fig. 44 the newer series, B, is seen to lie upon the older, A.

Now such a section as this (Fig. 44) would enable you to fix, relatively at least, the date of the mountain. You could assert positively that, first, there was a time when the mountain did not exist, but when its place was occupied by a sea in which the sedimentary rocks, A, were deposited; second, that the mountain was formed by the crumpling up of these rocks, and that this took place before any of the rocks of series B began to be formed; and third, that after the formation of the strata marked B the whole mass was further uplifted so as to raise these strata out of water into dry land.

But suppose that in some other part of the chain we discover such an arrangement of rocks as that shown in Fig. 45. Here, as before, we see that the series A

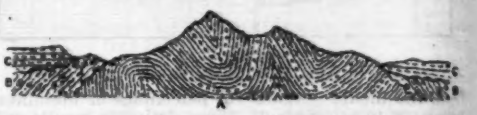


FIG. 45.—Section of a mountain in which the rocks, A, were upheaved before the series B, and the latter before series C.

was upturned before the series B could be laid down on it. But in the present case series B has also been tilted up out of its original horizontal position. Such a mountain would indicate three successive periods of upheaval, the first older than the time of B, the second older than the time of C, while the third came after the formation of C, for it raised that series of strata into land.

It is in this kind of way that the relative ages of mountain chains are determined. Wherever you meet with sedimentary rocks turned up on end or crumpled, you know that they have been disturbed, and whenever these disturbed rocks have their broken edges covered by others, you see that the uplifting must be older than the second set of rocks.

If now you could find out any means of recognizing the same series of rocks in different countries; if, for example, you could be sure that the groups A and B of Figs. 44 and 45 occurred both in England and Germany, you would be able to compare the relative ages of the mountains of the two countries. If in the one country a mountain shows the structure represented in Fig. 44, and if in the other country a mountain formed of the same series of rocks is built up in the way shown in Fig. 44, you would infer that the former mountain was newer than or, rather, had received a push upward after the latter.

In the next lesson it will be shown how geologists identify the same series of rocks in different countries, viz., by fossils. With this kind of evidence it becomes possible to decide which are the oldest and which the newest mountain chains. In this way we learn that the giant Alps, towering so far above the plains of Europe, are less ancient than many a green hill in Wales and Scotland.

But another singular and important fact about mountains is made plain by such sections as those in Figs. 44 and 45. The series of rocks marked A is the oldest part of the mountain in each case. You might naturally suppose that the oldest parts ought to be those which are buried deep under other portions. And yet on examination it is found that the most ancient parts are not always those which lie at the lowest level, but that, as in the two cases we have supposed, they may have been pushed up so as now actually to form the loftiest peaks and ridges. But if you get away to the flanks of the mountain, you find that the oldest rocks do really pass under the newer ones, as series A in the drawings passes under B.

The crumbling down of the surface of the earth is so constant and so widespread, that in process of time every mountain chain undergoes great and manifold changes. Its summits and sides are wasted and lowered. Its crests get splintered into peak and pinnacle, as the rains and frosts of ages do their work upon them. Crag and cliff are carved out of its sides; ravine and gorge, wider glen and still wider valley, are excavated in its rocks by the never ending flow of rill and river. Hence, though the original line of elevation remains, the upheaved tract is cut into innumerable ridges and valleys as the process of waste goes on.

So enormous have been the effects of that process over the surface of the earth, that great table lands

or broad masses of high land have been cut down into mere ridges and detached hills. In Fig. 46 you may as it were watch how the excavation proceeds. That is a drawing of part of a table land in Spain. You observe how the steams as they descend, and become larger in size, dig wider and deeper trenches out of the rocks, how their ravines widen out into valleys, how the high ground between them is being cut into irregular ridges, and how these ridges, still further cut into separate hills or mounds, lose height as the rains and frosts attack their summits and sides. In every quarter of the globe illustrations of these changes may be found. In Britain,

FIG. 46.—View of a table land cut into ridges and valleys by the flow of its rivers.

for example, our mountains are only fragments, like those in the drawing, which have been left after the excavation of the valleys that surround them. The great Ghauts of India, and the Table Mountain of the Cape, are likewise conspicuous instances of the same kind of origin.

The same forces which have carved out valleys and left mountain ridges standing out between them are still busy at their work. Every year adds to the waste. And thus, although when we gaze at a mountain chain we know that first of all it was heaved up by movements from below, we nevertheless learn to recognize that all the familiar forms which it now assumes have since that early time of upheaval been carved upon it by the very same forces—rains, frosts, springs, glaciers, and the rest—which are busy sculpturing its surface still.

V. How the Rocks of the Crust tell the History of the Earth.

When a historian betakes himself to write the history of a country, his first care is to make himself acquainted with all the scattered documents likely to throw light upon the transactions which he will have to describe. He ransacks the papers in the public archives and libraries, gleans what he can from printed books, and even it may be travels into foreign countries in search of contemporary writings which may explain what is dark or uncertain at home. Only after prolonged labor of this kind is he able to gather up the sum of all he has learned, and to weave it into a continuous narrative. In the course of his researches he will no doubt find some periods much better illustrated by contemporary documents than others, while of some he may possibly be hardly able to collect any satisfactory information, for in the course of time the papers which would have supplied him with the facts are lost or destroyed. Hence his history is not all equally full and reliable. There may even be gaps in it which no amount of industry in his search for information has enabled him to fill up.

Now what is thus true of the historian of any country is true also of the geologist. As already pointed out, and as must now be very clear to you, the earth has a history as well as the people who dwell upon its surface. A geologist may be called a historian of the earth. His great aim is to collect all the evidence which remains of the changes that have happened upon the earth's surface, and to arrange them in the order in which they have occurred, so as to show the grand march of events down to the present time.

What papers and inscriptions, coins and books are to the historian, the rocks of the earth's crust are to the geologist. They contain all the real evidence at his disposal. What he can gather from them at one place must be compared with what he collects from them at another. He must journey far and wide in search of facts which are not to be found at his own door. Gaps will certainly occur, which even the skill and industry of many years may never completely bridge over; for the rocks, as we have already seen, are subject to revolutions quite as destructive in their way as those which have swept away the archives of cities and nations. The geologist, therefore, can only at the best produce an imperfect chronicle. But it is one which has a profound interest for all of us, for it is the story of our own globe—of its continents and oceans, its mountains and valleys, its rivers and lakes, of the tribes of plants and animals which people its surface, and of the advent and progress of man himself.

Regarding the earliest stages of the earth's history, no direct evidence is now to be obtained from the rocks. When the earth was detached from its parent sun, it must have been a fiercely hot mass, as the sun is still. Not until long after that period could any such rocks as we now see have been formed. So that although the rocks carry us a vast way back into the past, they cannot bring us to the beginning of the earth's history as a separate planet. That early time can only be inferred from other and chiefly astronomical evidence.

In the foregoing pages you have learned how the rocks may each be made to give up its little bit of earth history. You succeeded in discovering, for example, from the rocks of a single quarry the site of an old sea floor with some of the remains of the sea creatures which lived upon it. Again, you found how a peat moss might enable you to trace out the limits of a long vanished lake on which our rude forefathers launched their oak canoes; and how the rocks of a coal pit could furnish forth a record of forest after forest which had each flourished green and fair at the surface, but which had sunk down one after the other, and were now buried deep within the earth.

In these and all such illustrations, while each series of rocks tells its own story, that story is only a part of the general history of the earth. The more carefully we can gather each separate narrative, the fuller will be that general chronicle of the earth's history which it is the object of geology to compile.

According to the law of superposition, the undermost stratified rocks are the oldest. We can reach but a little way down into the earth. The deepest mines descend but a very few thousand feet into the rocks. If, therefore, these rocks still lay flat as they were deposited, we should be able to make ourselves acquainted only with those near the surface. But in consequence of the way in which the rocks have been bent and broken and pushed up and down, we not only see the topmost parts of the series, but even some of the oldest masses. Instead of lying flat, the rocks are very commonly found to slope into the earth more or less steeply, and we can walk over their upturned edges, like the backs of so many rows of books. (See Figs. 38 and 39.) So far, therefore, from the bottom rocks being still buried under the thousands of feet of solid rock beneath which they once lay, they are often found rising into the summits of lofty mountain ranges. And thus the geologist is saved the trouble of sinking deep bores and pits to find out the order of the rocks under his feet. By making careful sections from what can be observed at the surface (as in Figs. 44 and 45), he determines that order with certainty, and when he has done so he knows which are the oldest parts of his chronicle and which are the newest.

The crust of the earth, so far at least as we can examine it, is chiefly made up of sedimentary and organic rocks. In these rocks, therefore, must the chief sources of evidence for the history of the earth be sought. If we could pile them up, one above another, in the order of their formation, they would form a mass probably more than a dozen miles thick. This, then, is the library out of which geological history must be compiled.

Besides the order of superposition, however, the geologist has another clew to the relative age of rocks. By comparing the different series of rocks with each other he has discovered that the fossils, or remains of plants or animals, of one series differ from those of another. For example, to turn again to Fig. 45, it is ascertained that if fossils occur in the set of rocks marked A, they will be found to differ from those in the series B, and these again from those in C. If, starting from the plants and animals of to-day, we go back into older and yet older rocks, we learn that the fossil plants and animals become, on the whole, more and more unlike those which are still living. Each great division of rocks is found to have its own characteristic fossils. So that, over and above the test by order of superposition, we can discriminate between these divisions by means of fossils.

By these methods of classification the vast complex mass of stratified rocks may be divided into a few great divisions, these into subdivisions, these again into minor compartments, and these into still smaller zones or bands, so that when a bed of rock is found it can be referred to its own particular part of the whole vast series. This method of arrangement is necessary for the sake of clearness, very much in the same way that a work on history requires to be divided into volumes, these into separate books, these again into chapters, and these into pages and lines.

Making use, therefore, of every kind of evidence which the rocks afford, the geologist endeavors to weave together his narration of the history of the earth. He shows how land and sea have often changed places, how time after time volcanoes have broken out in all quarters of the globe, how continents have, one by one, arisen, how mountain chains have been successively formed, how valleys, and ravines, and lakes have been excavated, how climates have slowly changed from tropic heat to Arctic cold. Amid all these revolutions of the solid earth itself, he finds that there have been at the same time vast changes in the plants and animals which have peopled its surface. He can trace how life, beginning in the remotest past with the simplest organisms, has advanced through long ages, in more and more highly organized forms up to the present time. He can mark how group after group of shells, or fishes, or reptiles, has come into existence, and, after living for protracted periods, has slowly died out to make way for newer tribes, until toward the close of the history man has appeared upon the scene.

Geological history brings before us, in this way, many facts well calculated to impress our minds with the great antiquity of our planet and with the marvelous chain of changes by which the present order of things has been brought about. We learn from it that mountains and valleys have not come suddenly into existence, such as we now see them, but have been formed gradually, by a long series of processes similar to those which are even now slowly doing the same work. We discover that every part of the land under our feet can yield us up its story, if we only know how to question it. And, strangest of all, we find that the races of plants and animals which now tenant land and sea are not the first or original races, but that they were preceded by others, these again by others still more remote. We see that there has been upon the earth a history of living things, as well as of dead matter. At the beginning of that wonderful history we detect traces merely of lowly forms, like the foraminifera of the Atlantic ooze. At the end we are brought face to face with man—thinking, working, restless man, battling steadily with the powers of nature, and overcoming them one by one, by learning how to obey the laws which direct them.

CONCLUSION.

It is not the design of this article to enter further into the history of the earth. It has led you to the threshold, whence you can see the kind of interest in store for you if you advance beyond. You have now learned something of the general principles upon which the history is based. Looked at in the light of geological teaching, the very stones of the street and the pebbles of the shore have each a meaning for you now. You will no longer be content to gather minerals and rocks merely because they are pretty objects to look at. Apart from their beauty, you will seek to discover what they are, and how they came to be where they are found.

A landscape will lose none of its beauty in your eyes though you seek to discover how the rocks of its hills were formed, how ridge and valley came into existence, why a crag should rise in one part and a wide plain stretch away for miles in another. When you stand by the brink of a foaming river, there will be no lessening of your pleasure in its rush and roar, if you think of the river as one of nature's most powerful engines, busy day and night in digging out its channel in the rocks, and carrying the waste of the mountains down to the plains and to the depths of the ocean. The shores of the sea will wear a new charm when you trace along their cliffs and caves the progress of decay, and on their beaches of sand and shingle the counterpart of those sedimentary deposits out of which whole mountains are built up.

Every quarry and ravine where the naked rock comes to view offers an attraction, if you seek to find there the remains of some of those lost forms of plants which covered the land, or of those long extinct tribes of animals which once tenanted the sea. These fossils will become, in your hands, not mere things to wonder at. You will try to learn from friend or book what they resemble most in the present living world. And you will not rest contented until you have seen all that you can discover of the light which they throw upon the former condition of the district in which you find them.

Geology will thus be no longer a task to be conned from books, but a delightful companion in every walk and ramble. You may never become geologists, but you will never regret the time you have spent in trying to master the principles on which geological science is based, and to trace out under their guidance the marvelous history of the earth.

[SCIENCE.]

THE PHYSICAL ASPECT OF THE PLANET MARS.

THERE has been so much said of late, in the newspapers and elsewhere, in regard to the parallel canals of Mars, that perhaps a brief discussion of the facts observed in regard to them may be of interest. And first of all it may be remarked that, of all the different methods of accounting for the appearances observed, perhaps the least probable is that they are water canals.

Let us see what are the facts in the case. According to the observations of Schiaparelli (*Reale Accademia dei Lincei*, 1881 and 1886), they lie almost entirely between 50° north and south latitude (that is, in the torrid and warmer portions of the temperate zones), and extend across the continent from the northern to the southern ocean. They are in general two or three thousand miles in length, though sometimes much longer, by from perhaps thirty to one hundred and fifty miles in breadth. They are generally arranged in pairs two or three hundred miles apart, drawn on the arcs of great circles, and so exactly parallel that usually no deviation can be detected. They run in all directions, but there are about a dozen points which seem marked as special centers from which they radiate. Thus ten start from the Trivium Charontis as a center, and eight from the Lacus Phœnicis. They cut up the continental surface of the planet so that there is no spot more than four hundred miles distant from one of these markings. They are usually so fine that no color can be assigned to them, and they can be merely spoken of as dark lines; but in a few instances where they broaden out, as in the Lyrtis Major (if this conspicuous marking can be considered one of them), they are decidedly darker than the oceans, and of a grayish or perhaps greenish tint.

Of a well defined canal, called by Schiaparelli Hades, M. Perrotin (*Annales de l'Observ. de Nice*, c. 39) remarks: "Since our first observations, the canal LN has suffered a considerable change; we can distinguish it no longer save to a feeble extent on the side marked N. Though drawn on the map of M. Schiaparelli of 1882, this canal does not exist on that of 1879. Our observations, then, not only confirm the changes already stated, but they show further that these changes may be produced in a short period of time." Other evidences of change have since been observed. It is thought that a large portion of the red region known as Libya had changed to green, and afterward in part back to red.

But the latest evidence of change, according to M. Perrotin (*Comptes Rendus*, cvi., 1738, and cvii., 161), is the carrying of several of the so-called "canals" across the northern ocean up to the polar ice cap. If the observation is correct, it is clear that either the ocean is not an ocean or the canals are not canals. If the observation were confirmed, I should be inclined to deny both propositions. Indeed, the northern ocean as represented by M. Perrotin at this point is but little more than an enlarged canal, while M. Schiaparelli does not indicate it at all upon his maps.

The latter has thought that many of these canals appear only for a short time, and then disappear again; and some of them he has only seen shortly after the passage of the vernal equinox on Mars, and thinks that there may be some relation between the two.

To every argument as to the inherent improbability of an hypothesis made with regard to a remote planet, we may be met by the statement that under different conditions these very things may happen—a statement easily made, and hard to refute. The best we can do, however, is to reason by means of the laws which we have found to apply in the case of the earth. Certainly no such straight canals could be made here naturally, and, if they were made, they would soon be filled up again. If, on the other hand, the canals were artificial, what could be the use of making them so wide, why arrange them always in duplicate, and why fill certain of them up every year, later to be reopened? Think of the labor involved in covering over, and then reopening, a canal say sixty miles wide by three thousand miles long, and all in the space of a few weeks. Moreover, in the case of those which are sufficiently wide for us to see distinctly, why should the color be so much darker than that of the neighboring oceans?

Mr. R. A. Proctor has suggested (*Monthly Notices Roy. Ast. Soc.*, xlviii., 307) that the canals are the diffraction images of rivers produced by mist which hangs over the river beds. To this suggestion, however, some of the same objections apply as to the other.

M. Fizeau's suggestion (*Comptes Rendus*, cvi., 1359), that the stripes are cracks between huge masses of ice,

presents some difficulty in accounting for the red color of the ice; and also, as was pointed out by M. Flammarion (*Comptes Rendus*, cvii., 10), since the temperature of Mars, as indicated by the size of the polar spots, is, if anything, higher than that of the earth, it is surprising that the ice does not melt.

Before going further, let us see what is the probability that these supposed markings are really genuine. Several astronomers—Dawes, Perly, Burton, and others—have independently constructed maps of Mars, or made observations from which such maps could be constructed; and it is found, on comparison, that a number of these stripes are common to several of the maps. It is therefore probable that these particular stripes are really there. M. Perrotin has confirmed the doubling of the stripes previously mapped by M. Schiaparelli; it is therefore quite possible that these are genuine also, although the observation is one of extreme difficulty, requiring the steadiest possible atmospheric conditions. But the statement that a change in the markings has been observed is one that must be received with extreme caution, and, although a most interesting one, must for this very reason be only accepted as proved when confirmed by observations made with the most powerful telescopes at our disposal, and under the most favorable circumstances.

Starting out from the generally accepted fact that there are stripes upon the planet, we find there are five possible hypotheses to explain their existence. Three, that they are due to water in the vaporous, liquid, or solid condition we have already noticed. Fourth, we may explain them by supposing them to depend on the color of the rock or soil, and that their shape depends on some peculiar geological formation. We have, to be sure, no such formations upon our globe; but we have something analogous, though on a somewhat smaller scale, upon the moon. There we find numerous long narrow streaks radiating from the crater Tycho, as also in a lesser degree from some of the other craters. The streaks are perfectly straight, of very light color, and in a few cases we find them arranged parallel to one another.

As to the color of Mars, it is probable that the earth would appear of the same color as seen from a distance, if deprived of its vegetation, owing to the red color of its soil in most parts of the world, particularly in the warmer regions.

If it can be shown, however, that at certain seasons the stripes on Mars really disappear, through some other cause than that of passing clouds or haze in its own atmosphere, then this hypothesis, like that of the water canals, must fail.

The fifth and last of the possible explanations is that the stripes are due to differences in vegetation. Whether the stripes indicate vegetation, and the rest is a barren waste, or whether a large proportion of the vegetation of Mars is of a reddish color, as suggested by Lambert among others, and approaches in tint to our coleus and autumn leaves, is a matter of no consequence at present. If it can be shown that the stripes on Mars really change, this will be the hypothesis that we shall be forced to adopt, or, rather, we should say it is the only one left presenting no serious improbabilities.

Let us now review the already ascertained facts with regard to the planet. We are reasonably certain that the surface of Mars is composed of land and water; that it has snow at its poles, and therefore an atmosphere containing clouds. As the snow does not extend over the whole planet, but varies in extent at different times, and what are apparently clouds have been observed in other regions of its surface, it is probable that they likewise have rain. Their temperature cannot be very different from ours, judging by the extent of the snow at the poles, which is rather less in proportion than with us, and has in some instances been known to entirely disappear. Their days are but forty minutes longer than ours; and their seasons, owing to the inclination of the axis of Mars, are practically the same. The most marked difference between the two planets of which we are certain is that, owing to the lesser attraction of Mars, bodies there would weigh but two-fifths as much as with us; a man, for instance, weighing one hundred and sixty pounds here would weigh but sixty-four pounds upon Mars. All the conditions, as far as we can determine, save that their sunlight is somewhat weaker, are as favorable to the growth of organic life there as here.

The spectroscope teaches us that the same elements are found throughout the universe; therefore, if we define vegetable life as consisting of organized structures absorbing carbonic acid and giving out oxygen, it will be seen that the admission that vegetable life exists upon Mars carries with it animal life also as a corollary, or vegetation would soon cease for lack of fresh air.

As Mars is a smaller planet than the earth, and more remote from the sun, it probably reached a suitable temperature to support organic life at an earlier date. The laws of evolution have therefore had sufficient time to develop reasonably highly organized animal as well as vegetable life.

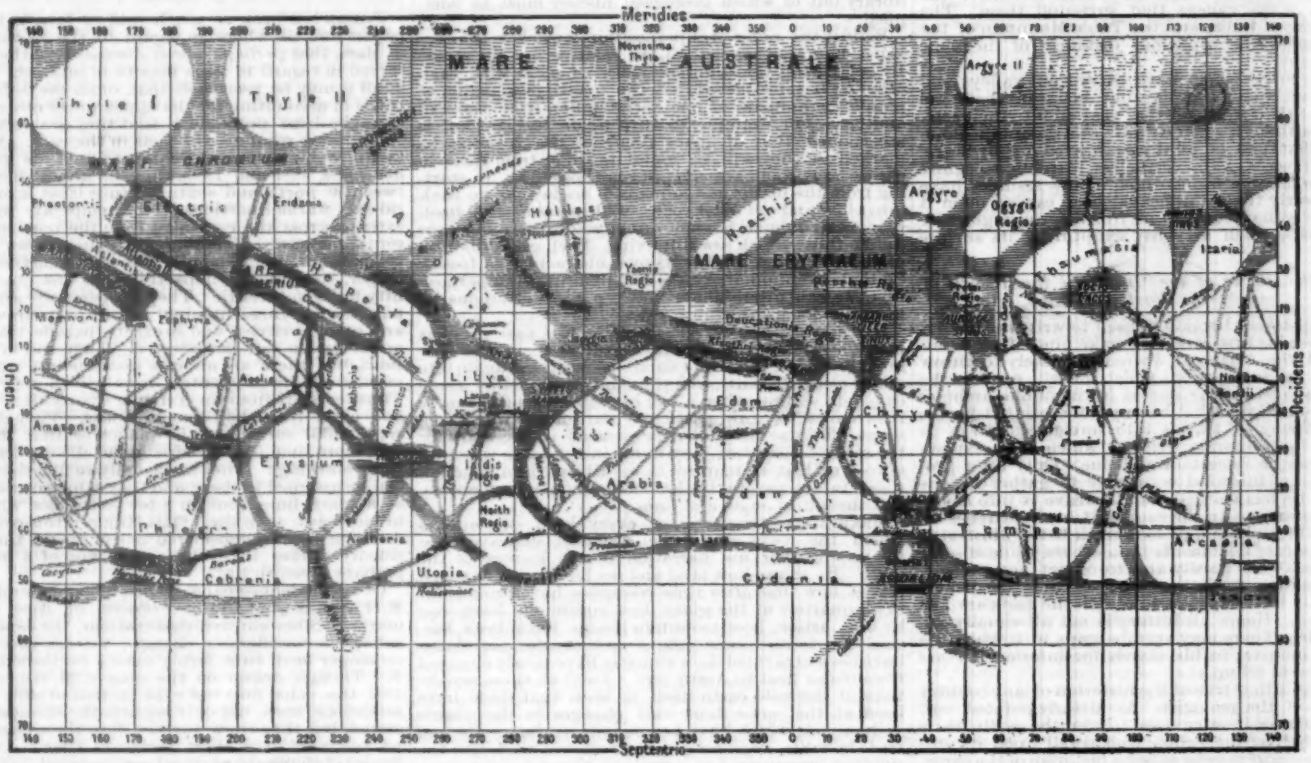
This is as far as we are justified in carrying our hypothesis, unsupported by other facts; but now let us give rein to our fancy for a moment, and suppose an observer on Mars were to examine the earth with successive increasingly powerful telescopes. The first artificial production that he would probably be able to see would be some of the great grain fields of our Western States. These he would find of irregular shape, but bounded more or less by straight lines. They would appear of a greenish color, not very different from that of our oceans; and he would find them subject to great changes at certain seasons, sometimes perhaps entirely disappearing from sight, when of the same tint as the surrounding country. In fact, if an observer were placed on Mars, and furnished with one of our more powerful telescopes, he would see just about as much of our grain fields as we do of their stripes, and the only noticeable difference between the two would lie in their shape. Indeed, assuming an artificial origin, it would be easy to frame hypotheses accounting for their form, dependent upon the peculiar conformation of the land surface of Mars, or for their radiating in several instances from particular points as centers.

But to return to our hypothesis, that the stripes are of vegetable origin. If it is correct, there is one test to which it must submit. If a change is noted in a given stripe, this change should be in general more or less progressive from the equator toward the poles, or *vice versa*. I say in general, because it is not probable that the same kind of vegetation would exist all the way from the equator to 50° north or south latitude, nor would it be the same in all stripes having the same latitude. Moreover, in the stripes running east and west, or in those situated near the equator, successive changes would not usually be noticeable. Stripes containing the same kind of vegetation should be similarly affected. Now, in the stripe known as Hades, previously referred to, this very phenomenon was observed. Hades runs in a direction nearly north and south, and extends from latitude 20° to 45° north. The observation in question was made about two and a half of our months after the passage of the northern solstice on Mars. It was therefore in the latter part of their summer when it was found that the southern portion of what had but a few weeks before been a well defined stripe had completely disappeared.

As an illustration of the formation of a stripe running from the equator toward the pole, let us take the latest observations of M. Perrotin (*Comptes Rendus*, cvii., 161). According to these observations in the regions as far north as between latitudes 50° and 60°, the stripes did not appear this year until June 4, or four months after the summer solstice. Unfortunately, Mars is now getting so near the sun that it will be probably impracticable to determine the date of their disappearance, should they be found later to have vanished.

WM. H. PICKERING.

Observatory, Cambridge, Mass., Aug. 9.



A MAP OF THE PLANET MARS.

PROGRESS IN GREECE.

DURING recent years the material progress which has been made in the kingdom of Greece has been very considerable; but it has not attracted in this country the attention it deserves. Various magazine articles and pamphlets have from time to time been published, and although some of them called forth a few remarks, they were soon passed over and forgotten. A book has just been issued by Mr. Effingham Wilson, London, from the pen of Mr. Charles Cheston, M.A., which ought to be read with attention by those whose interests are connected in any way, either directly or indirectly, with Greece. It is entitled "Greece in 1887," and every page of it bears testimony to careful work. The author is evidently enthusiastic about Greece, both ancient and modern, and possibly his enthusiasm may have carried him a little too far on a few points; but a great part of the book is taken up with the narration of facts about which there can be no dispute, and its chief object is to enlist the interest of the industrial and financial classes of this country in Greece, as a field for commercial enterprise, which would be beneficial to both nations. The author observes that "Greece and its resources are worthy of more attention than they meet with in England. Although it is a poor country, and large portions of the soil are rocky and ungrateful, the plains of Thebes and Lebadeia are of great fertility; and in the alluvial lands that border on Lake Copais the soil is so rich that cotton crops have been grown on it for thirty years, with peasant cultivation, and little or no manure. The Peloponnese, with a population which does not exceed 400,000 persons, produces crops of an annual value of from 80 to 90 million francs—a result which is scarcely equaled anywhere in Europe. In the two large Thessalian plains, which are now opened up and put in direct communication with the port of Volo by the Thessalian railways, there is room for hundreds of thousands of colonists."

The great difficulty in the way of the development of Greece has been the want of internal railway communication, for although there are isolated lines of railway, the greater part of the country is still shut off from communication from the coast. At present, however, projects are in hand for coupling Greece to the main European system of railways, and some lines from the ports to the interior are proposed. These are largely in the hands of French engineers and contractors, whose enterprise reflects on the indifference of British capitalists and contractors. It must be admitted, however, that the French have a great advantage, as their language is the second language in Greece; the government's engineers are French, and the reports of some of the government departments are written in French. Mr. Cheston gives interesting accounts of the material progress during recent years, of the different kinds of goods imported, of the railways which have been made, of the mines which are being worked, of the products of the country, and the shipping which entered and left its ports in the year 1886. Regarding its finances, he is of opinion that the recent heavy expenditure has not crippled the resources of Greece, and that the income of the country is sufficient to provide, without any undue pressure on the people, not only for the expenses of government, but for the interest and sinking funds on its debt, heavy as is the rate of interest in many cases; and the equilibrium which has been restored in the annual accounts, coupled with the rise in the value of Greek securities, points to the probability at an early date of some readjustment of the conditions of at least the older public loans.

In Greece, as in other countries, we hear of the competition of France and Germany in every department of industry. The British consul at the Piræus reports that for one English commercial traveler in the Levant there are twenty Germans and Frenchmen, as a result of which German hardware goods, being cheaper, although somewhat roughly made, have entirely superseded English manufactures. The whole of the rails and rolling stock of the Piræus and Patras Railway were imported from Germany, and those of the Thes-

alian lines from Belgium, while the last six government torpedo boats were built in German dockyards. But for details of these and many other matters we must refer our readers to Mr. Cheston's book, which is well worthy of careful study.—*Industries.*

THE MAURER HELIOGRAPH.

For some years past, the automatic inscription of the hours of the sun, which was begun by Messrs. Campbell & Stokes, has formed a part of the daily observations in several meteorological or climateric stations. The apparatus used for such inscription are

FIG. 1.—MAURER'S HELIOGRAPH.

divided into two categories, in one of which the calorific properties of the solar rays are utilized, and in the other the insolation is measured by means of the chemical properties of light. The durations of the insolation inscribed by the different radiations of the spectrum agree pretty well in most cases, but it may happen that certain of the radiations, especially the least refrangible ones, will be absorbed by a light mist, and that a part of the hours inscribed by one of the apparatus will be lost by the other. We do not yet know exactly the relative importance of the various radiations of the spectrum in the development of meteorological and physiological phenomena.

Everything was formerly attributed to calorific effects. To-day, we know that the invisible rays or the luminous rays deprived of heat are capable of producing very marked physiological effects. Some experiments made a few years ago by Mr. Siemens demonstrated that the electric light exerts a certain influence upon the growth of plants. Very recently, again, experiments on the electric welding of metals, for which very intense voltaic arcs were employed, were followed by serious physiological disorders among persons who were present. Although all the assistants had protected their faces with plates of dark glass, they soon felt pains similar to those produced by violent insolation. Several were attacked with conjunctivitis, and the skin peeled off the face as if the latter had been burned. This phenomenon was spontaneously named "electric sun stroke."

The effects of different radiations upon meteorolgical phenomena are less easily ascertained, and they are not yet sufficiently well demonstrated, we think. Doubtless, heliographs will help to explain them.

If, now, independently of the relations between the inscribed rays and the phenomena that they produce, we consider the apparatus from the sole standpoint of the inscription of the duration of the insolation, we shall see that photographic apparatus give more accurate results than calorific ones do. In fact, in these latter, the spot produced upon a band by the combustion engendered in the focus of a spherical lens is necessarily quite large, so that, on the one hand, interruptions of a few minutes in the insolation may completely disappear in a uniformly burned line, and, on the other, the humidity that deposits upon the band and the moisture that may cover the ball prevent the combustion from taking place. It thus happens that the indications of the combustion heliograph are appreciably falsified. In recent times, several photographic heliographs have been devised. The one lately constructed by Dr. Maurer, an attache of the central meteorological bureau at Zurich, is distinguished by the great simplicity of its form and its diagrams. It consists of a cylindrical brass drum cut off obliquely and having a cover in the center of which there is a small rectangular aperture. The bottom of the cylinder is movable and is kept in place by a bayonet catch.

When the cylinder is oriented in such a way that its axis is parallel with the terrestrial axis, the solar rays passing through the aperture in the cover describe in one day a circular upright cone (the declination of the sun being supposed constant in the course of the day) around the axis of the cylinder. The trace of the rays on the inner surface of the latter will be given by the intersection of these two surfaces (Fig. 3). It will be easily seen that this trace is a circle whose plane is at right angles with the axis of the cylinder. If, then, the cylinder contains a sheet of photographic paper (blue or ferrocyanide of iron), the passage of the solar rays will be marked by a circle, which in the development of the sheet will become a straight line.

The cylinder is placed in the position that it is to occupy as follows. The N. S. line traced upon the cover is first oriented in the meridian; then the platform is leveled by means of leveling screws; and finally the arc of a circle that carries the cylinder is brought to such a position that the index marked upon the frame indicates on the division the latitude of the place. If the instrument has been especially constructed for the place of observation, the cover is then horizontal; if

FIG. 3.—DIAGRAM OF THE CIRCULAR TRACE OF THE SOLAR RAYS.

not, it may be slightly inclined upon the horizon. The apparatus are constructed for various definite latitudes, but can be used in others that differ from them by a few degrees.

Fig. 2 shows a series of bands, with inscriptions obtained at Neuchatel from the 10th to the 30th of September, 1887. The vertical lines correspond to the hour of the day and are ruled upon the paper beforehand.

These observations, which have a certain importance in meteorology, have the advantage of being very easily made. Moreover, they have so much interest for every one that amateurs may find pleasure in daily obtaining bands burned or marked photographically by the passage of the solar rays. It is thus possible to collect from year to year perfectly authentic data as to the state of the weather. On adding to these, observations upon other phenomena, such as the growth of plants, for example, we shall certainly be able to make interesting comparisons.—*La Nature.*

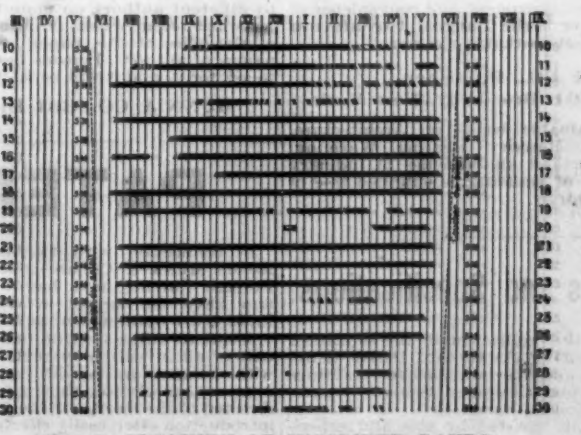


FIG. 2.—SPECIMEN OF INSCRIBED BANDS.

[NATURE.]

VEGETABLE RENNET.

THE idea that the protoplasm or living substance of both animals and plants is essentially similar, if not quite identical, has long been accepted by both physiologists and botanists. This similarity is most easily seen in the very lowest members of both kingdoms; in fact, for a very long time doubt existed in the case of many organisms—e. g., Volvox—as to which kingdom they should properly be included in. Even now it is hardly possible to formulate a definition of "plant" or "animal" which shall put all into their proper positions. When we go higher up the scale in both the animal and the vegetable world, this difficulty, of course, disappears, on account of the differences of organization and development. It is not difficult even here to trace a remarkable similarity of properties in the living substance, which leads to the conception that not only is protoplasm practically the same in animal and vegetable, but that its activities in the two cases—that is, the metabolic processes which accompany, and are in a way the expression of, its life—are fundamentally the same. In both kingdoms we have as the sign of its life the continual building up of the living substance at the expense of the materials brought to it as food, and the constant breaking down of its substance with the consequent appearance of different organic bodies, which are strictly comparable in the two cases. The vegetable protoplasm produces starch, the animal glycogen—both carbohydrate bodies of similar composition and behavior. In both organisms we meet with sugars of precisely similar character. The proteid bodies long known to exist in animals, and classed into albumins, globulins, albumoses, peptones, etc., have been found to be represented in vegetables by members of the same groups, differing but in minor points from themselves. We have fats of complex nature in the animal represented by oils of equal complexity in the vegetable, their fundamental composition being identical; even the curious body lecithin, so long known as a constituent of nervous tissue in the animal, having been procured from the simple yeast plant.

Further, the changes which give rise to these bodies, or which bring about various transformations of them, have been in very many cases demonstrated to be due to similar agencies at work in both the animal and vegetable organism. In many cases, no doubt, they are produced by the actual splitting up of the protoplasm itself; but apart from this we have their formation in large quantities by the agency of bodies which are known as unorganized ferments, and which are secreted by the protoplasm for the purpose of such formation. Perhaps no line of research in vegetable physiology in recent years has been so productive of good results as the investigations that have been made into the occurrence of such bodies, and the comparison of them with those that are met with in the animal organism. Diastase in vegetables, and the ferments of saliva and of pancreatic juice in animals, possess the same power of converting starch into sugar. The peptic and trypeptic ferments of the stomach and pancreas respectively have been shown to have representatives in the vegetable kingdom, and these not only in such cases as the carnivorous plants, but to be actually made use of in such truly vegetable metabolism as the processes involved in the germination of the seed. The conversion of albumins and other indiffusive proteids into a further state than that of diffusible peptone—that of leucin in the animal, and asparagin in the vegetable—has been shown to be the work of such a ferment in the two cases. These ferments, too, are interchangeable to a certain extent, for those of the alimentary canal are capable of digesting the proteids of vegetable bodies, while those of the latter can similarly split up the animal albumins, fibrin, and other forms of proteid.

The essential similarity of the metabolism is also indicated by the appearance in the two cases of complex bodies of somewhat similar constitution which are quite comparable with each other. In the vegetable kingdom these bodies are known as alkaloids; in the animal they have for the past ten years or more been known as ptomaines. They are among the products of the destructive decomposition of proteids. Thus *cadaverin*, a body found in putrefying animal matter, is apparently to be looked upon as belonging to the same group of bodies as *muscarin*, the poisonous principle found in several species of mushroom.

Perhaps the latest development of the same idea has been the discovery of ferments in the vegetable kingdom which are comparable in their action with the rennet which is obtainable from the stomach of many young animals, particularly the calf. In an extract of such a stomach taken while secretion of gastric juice is proceeding, or in the gastric juice itself, is a principle which has the power of curdling milk—a property taken advantage of by the farmer in the process of manufacturing cheese. The *casein*, which is the proteid concerned in cheese-making, is, under appropriate conditions, converted by this body into an insoluble form, which, for want of a better name, may be called briefly cheese. The conversion is not to be confused with the loose curdling which takes place when milk becomes sour from putrefactive changes or from the addition of an acid, for it is a true coagulation, resembling the clotting of blood. Now, recent investigations show us that in many plants a similar ferment exists, which possesses an identical power, producing, when added to milk, a clot which is quite indistinguishable from that which is formed under the action of animal rennet. The list of such plants is continually increasing, but they do not appear to be grouped at all on the lines of the recognized natural orders. Ranunculaceæ, Solanaceæ, Cucurbitaceæ, Compositæ, Galiaceæ, and others, furnish us with conspicuous examples.

At a meeting of the Society of Natural Science of Stockholm, held about four years ago, the secretary brought before the notice of the meeting the fact that the common butterwort (*Pinguicula vulgaris*) possessed the very curious property of causing a clotting of milk when the vessels in which the milk was contained had been first rubbed over with the plant. No explanation was offered of the phenomenon, but a suggestion was made that the power might be due to the presence of micro-organisms. Judging from analogy with other plants since discovered to possess the same property, it is far more likely to be due to a specific

unorganized ferment. The occurrence of this in Pinguicula is very significant, as bearing on the similarity of the metabolism in animals and vegetables, for Pinguicula is one of the carnivorous plants, digesting, by the aid of its secretions, flies which it captures in its leaves. We have so associated in the same plant a proteolytic and a rennet ferment—a condition which at once recalls the gastric juice of animals, in which both these bodies are present.

One of the most interesting of the plants which contain this ferment, or vegetable rennet, is the so-called "Naras" of the West Coast of Africa (*Acanthosicyos horrida*), a species of Cucurbitaceæ. The plant was described in detail by Welwitsch, in 1869, when its peculiar physiological property was unknown. A more detailed description, given by Marloth, has recently appeared, which deals, among other points, with this power. The plant is to be met with in dry, sandy, and desert places in Namaqua Land, Whale Bay, and the Mozambique district. It is very singular in its habit and appearance, consisting of long, spiny, weak-looking branches running almost on the surface of the sand, and being at intervals buried therein and again emerging. The stem is very short, so that the plant looks like a system of creeping spiny branches, some of which measure 20 feet or more in length. The root system is similarly developed, long creeping roots penetrating, in some cases, for a distance of 100 feet through the sand. The long spiny branches seem destitute of leaves, for these are quickly deciduous and sometimes abortive, and while they remain upon the shoots they are closely adpressed to them, and are stiff and horny in texture. At the base of each leaf are two strong spines, which persist after the leaf has fallen. The flowers are borne in the axils of the leaves, between the spines. The male and female flowers are found on separate plants; the former are sessile, the latter shortly stalked. The ripe fruit is of considerable size, much like an orange in appearance. It has a very powerful and pleasant aroma, and its pulp is very juicy and agreeable to the taste. In the unripe condition it is bitter and uneatable. According to Marloth, the natives eat it to a very great excess, both fresh and in the form of "Naras cake," a preparation of it made by drying the expressed pulp and juice in the sun. The power to appreciate its excellence seems to be confined to the natives of the part, for strangers partaking of it for the first time are said to pass through strange and painful experiences after their banquet.

Its power of causing the clotting of milk is well known among the natives of the part, who use it freely for that purpose. The ferment is contained in considerable quantity in the juice, the pulp, and the rind of the fruit. It is absent from the branches, from the seeds, and from all parts of the unripe fruit. It is soluble, according to Marloth, in alcohol of sixty per cent. strength, an extract of the pulp made with that fluid retaining the power to coagulate the milk. It is not identical with the principle which gives the fragrance to the ripe fruit, nor to that which gives the bitter taste to it when still young. The ferment is destroyed by boiling, but will remain for an almost indefinite time in the dried rind. Marloth, in his experiments, found that an extract of pulp dried to a friable condition in the sun was quite active in causing coagulation. The writer had the opportunity recently of examining some dried rind and some old seeds.* An extract of these materials, made with five per cent. solution of common salt, showed the ferment in abundance in the rind, but absent from both the testa and the interior of the seeds.

Another plant, occurring nearer home, has the same property. This is the common yellow gallium (*G. verum*). In his "Popular Names of British Plants," Prior speaks of its peculiarity as being known in the sixteenth century, when Matthioli wrote of it, "Gallium inde nomen sortitum est suum quod lac coagulet." In the west of England, particularly Somersetshire and Herefordshire, it is still the custom of dairymen to put this plant into the milk they have devoted to cheese production, to "set" it. The plant has a long straggling stem, bearing at short intervals whorls of small leaves, in the axils of which are numerous panicles of yellow flowers. The practice is to add the whole plant, or as much of it as is above ground, into the milk, but the active principle seems to be concentrated in the flowers. The white gallium (*G. Aparine*) is said to be devoid of the property.

The common traveler's joy (*Clematis Vitalba*) is another instance of the occurrence of this ferment. It is peculiar in one respect, the property appearing to be situated in the tissue of the stem, probably the soft bast. In most other cases, it seems to be attached somehow to the reproductive parts of the plant. The quantity that can be extracted from clematis is, however, much less than from the other plants spoken of.

The ferment has also been found in the petals of the artichoke (*Cynara Scolymus*).

An account of the occurrence of this vegetable rennet would not be complete without its including the researches of Dr. Sheridan Lea on *Withania coagulans* (Proceedings of the Royal Society, 1883). These have, besides their scientific value, a direct bearing upon the commercial aspect of the question. Many of the natives of India refuse to have anything to do with cheese prepared by means of animal rennet, and there is consequently there a large field for the employment of the plant. Some years ago Surgeon-Major Aitchison sent home an account of the peculiar property of the withania. The shrub grows freely in Afghanistan and Northern India, and the natives there have for a long time employed an aqueous extract of the capsules to curdle their milk. Some dried material sent from thence to Kew was used by Dr. Lea in his investigations. Withania is a genus of the order Solanaceæ and has a capsular fruit, containing a large number of small seeds. In the dried material, these seeds were enveloped in a coating of a peculiar resinous matter, which was probably the dried juice of the capsules in which they had ripened. The ferment was found to exist to a very slight amount in the stalks of the fruits, and to be extremely abundant in the seeds. From the ground seeds it could be extracted easily by maceration with solution of common salt, and by treatment with glycerine. So extracted, it was found to be destroyed on boiling, but to be able to withstand moderately prolonged exposure to alcohol. Its activity in a fairly strong extract was quite equal to that of most commercial samples of rennet prepared from the stomach. It could, moreover, be kept with as great security as the latter, by the aid of common salt and a little alcohol. Its commercial value is somewhat interfered with by the presence in the seeds, and in their extracts, of a peculiar yellowish-brown coloring matter, which cannot be separated without destroying the rennet.

Since the publication of Dr. Lea's researches, the writer has met with the ferment in the unripe seeds of *Datura Stramonium*, a plant belonging to the same order, Solanaceæ. In this plant, though present in the unripe seeds, it appears to be absent from them when ripe. Its exact distribution is, however, not yet determined.

The occurrence of this property in so many plants, and these not at all closely connected in other ways, leads to the consideration of what must be its physiological significance. It is perhaps not difficult to see why rennet should occur in the stomachs of young animals, whose food consists chiefly of milk, but its importance in the vegetable kingdom must be independent of such a function. Further researches, still in progress, may, perhaps, throw some light upon this point. It is significant so far to notice that its occurrence is mainly in those parts which are especially connected with the reproduction of the plant, a fact which seems to point to a possible function in connection with the storage of proteid food materials for the nutrition of the embryo during germination.

J. R. GREEN.

* This material was kindly furnished by Mr. W. Thiselton Dyer, F.R.S., director of the Royal Gardens, Kew.

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